The Engineer

UNIVERSITY OF MICHIGAN
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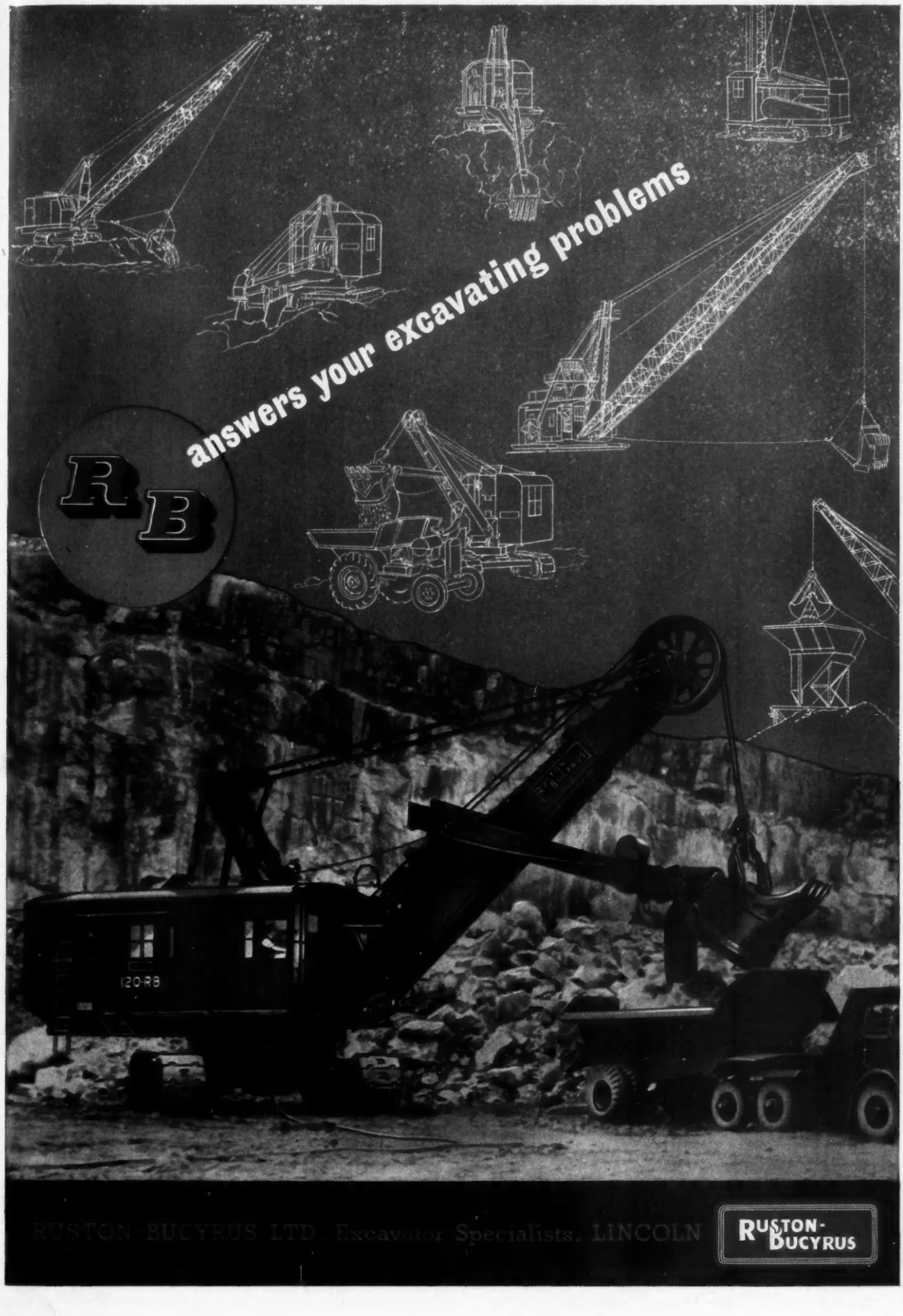

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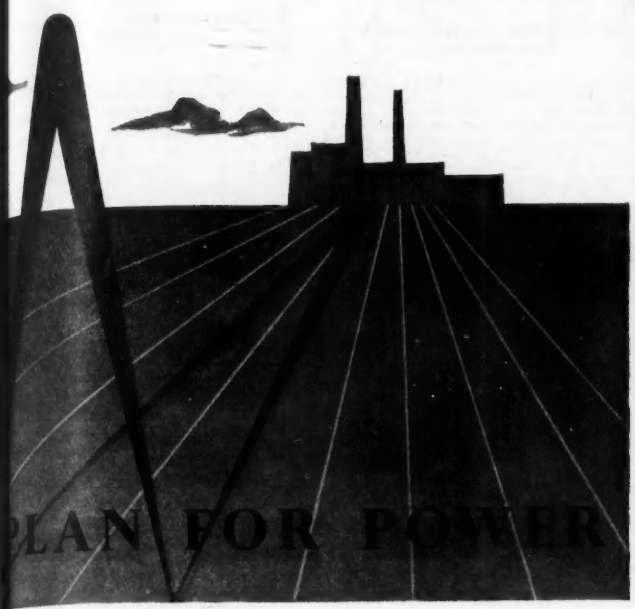

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1

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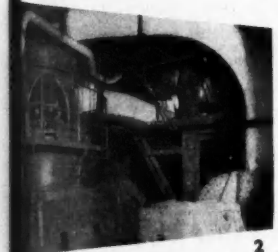
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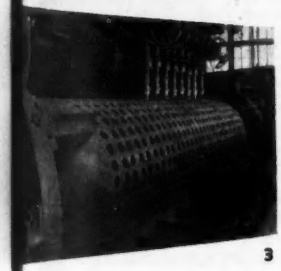
3

1. *Power expanding of tubes inside a boiler drum.*
2. *One of two Raymond Bowl Mills and exhauster fans firing one water-tube boiler.*
3. *Multiple spindle machine trepanning tube holes after fabrication.*

TER-TUBE BOILERS BY Clarke Chapman

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THE ENGINEER

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NOTICE TO READERS

All letters intended for insertion in 'The Engineer' or containing questions should be accompanied by the name and address of the writer, not necessarily for publication, but as a proof of good faith. No notice whatever can be taken of anonymous communications. No undertaking can be given to return drawings or manuscripts; correspondents are therefore requested to keep copies.

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WORDING OF ADVERTISEMENTS: Approximately the first 25 letters of each advertisement are set in heavy type. Advertisers are therefore advised to begin their advertisements with the words they want emphasized.

Advertisements received by Mid-day Tuesday will appear in the issue of Friday the same week. Orders must be accompanied by a remittance.

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PUBLIC APPOINTMENTS

UNIVERSITY COLLEGE OF SOUTH WALES AND MONMOUTHSHIRE

CHAIR OF ELECTRICAL ENGINEERING

Applications are invited for the CHAIR OF ELECTRICAL ENGINEERING. Salary £1700, rising after five years to £1800 per annum. The successful candidate will be expected to take up his duties as soon as possible. Applications should be received on or before November 14th, 1953, by the undersigned, from whom further particulars may be obtained.

(Signed) E. R. EVANS,
Registrar.

Cathays Park, Cardiff,
3rd October, 1953. E5607

COUNTY BOROUGH OF ROTHERHAM EDUCATION COMMITTEE

ROTHERHAM TECHNICAL COLLEGE

Principal : Mr. G. E. COOKE, M.A.

ASSISTANT, GRADE A

Applications are invited for appointment as ASSISTANT, Grade A, in the Department of Mechanical Engineering, to commence duties as soon as possible.

The work of the Department includes Final Examinations for City and Guilds, Higher National Certificates in Mechanical Engineering and Production Engineering, and External Degrees of London University in Mechanical Engineering. Facilities are available for research.

Candidates should possess a Degree or equivalent qualification and should preferably have had industrial experience.

Salary in accordance with the Burnham (Technical) Scales, 1951 (£415–£670 per annum).

Application forms may be obtained from the undersigned, to whom they should be returned within a fortnight of the appearance of this advertisement.

R. BLOOMER,
Director of Education.

Education Offices,
Rotherham. E5556

GLAMORGAN EDUCATION COMMITTEE

PRINCIPAL

Applications are invited for the permanent appointment of PRINCIPAL at each of the following Colleges :—

Aberdare College of Further Education, Gorseinon College of Further Education.

Applicants must be Graduates of a University in the United Kingdom, with First or Second-Class Honours or Higher Degree in Science or Engineering. Candidates will also be required to have had varied experience in further education, involving both teaching and organisation. Present salary scale is £950 by £50 to £1100 per annum, plus a special addition of £40 per annum. Application forms and further particulars obtainable from the undersigned on receipt of a stamped, addressed, foolscap envelope. Closing date 22nd October, 1953. Canvassing will disqualify.—Emlyn Stephens, Director of Education, County Hall, Cardiff. E5586

CITY OF SHEFFIELD

RESIDENT ENGINEER, COLLEGES OF TECHNOLOGY AND COMMERCE

Applications are invited for this appointment to supervise the foundation and superstructure contracts for the above building, under the direction of Messrs. Gollins, Melvin, Ward and Partners, Chartered Architects of London, in association with the City Architect (Mr. J. L. Womersley).

The salary will be £1000 per annum.

Candidates must have considerable experience of large-scale structures in city areas involving site excavation, shoring, reinforced concrete and steelwork erection. Only applicants possessing such experience and a recognised examination qualification will be considered.

The post is established for the duration of the contract which may be several years, but the appointment will be subject to one month's notice on either side.

Applications, stating age, qualifications, present and past appointments (with dates and salaries), experience and the names of two referees, should reach the undersigned by the 19th October, 1953.

JOHN HEYS,
Town Clerk.

Town Hall,
Sheffield, 1. E5617

SURREY EDUCATION COMMITTEE

COUNTY TECHNICAL COLLEGE, STOKE PARK, GUILDFORD

SENIOR LECTURER

Applications are invited for the post of SENIOR LECTURER in Mechanical Engineering to commence duties on 1st January, 1954. Candidates should be Graduates and preferably Corporate Members of the Institution of Mechanical Engineers ; they should have good experience in technical teaching and in industry.

Salary scale for Senior Lecturers is £1040 by £25 to £1190 per annum.

Application forms and further particulars may be obtained from the Principal, to whom completed application forms should be returned within ten days of the appearance of this advertisement. E5593

PUBLIC APPOINTMENTS

CIVIL SERVICE COMMISSION

SENIOR SCIENTIFIC OFFICERS, SCIENTIFIC OFFICERS, PATENT EXAMINER AND PATENT OFFICER CLASSES

The Civil Service Commissioners invite applications for permanent and pensionable APPOINTMENTS to be filled by frequent competitive interviews. The Scientific Posts are in various Government Departments and cover a wide range of scientific research and development in most of the major fields of fundamental and applied science. In biological subjects the number of vacancies is small ; individual vacancies exist at present for candidates who have specialised in palaeobotany and foraminifera. The Patent Posts are in the Patent Office (Board of Trade), Admiralty and Ministry of Supply.

Candidates must have obtained a University Degree with First or Second-Class Honours in an appropriate scientific subject (including engineering) or in Mathematics, or an equivalent qualification ; or for Scientific Posts, possess high professional attainments. Candidates for Senior Scientific Officer Posts must, in addition, have had at least three years' post-graduate or other approved experience.

Age limits : Senior Scientific Officers, between 26 and 31, but specially suitable candidates under 26 may be admitted. For Scientific Officers and Patent Classes, between 21 and 28 during 1953 (up to 31 for permanent members of the Experimental Officer Class competing as Scientific Officers). Inclusive London salary scales : Senior Scientific Officers, (men) £917–£1075 ; (women) £681–£917. Scientific Officers, (men) £440–£812 ; (women) £440–£576. Patent Examiner and Patent Officer Classes, (men) £440–£760 ; (women) £440–£576. Women's rates under review. Somewhat lower rates in the Provinces.

Further particulars from the Civil Service Commission, Scientific Branch, Trinidad House, Old Burlington Street, London, W.1, quoting No. S.53/53, for Senior Scientific Officers, and S.52/53, S.128/53, for the other posts. Completed application forms to be returned on or before 31st December, 1953. E5591

SURREY EDUCATION COMMITTEE

WIMBLEDON TECHNICAL COLLEGE, GLADSTONE ROAD, S.W.19

LECTURER IN MATHEMATICS

Applications are invited for the post of LECTURER IN MATHEMATICS. Preference will be given to Graduates with previous experience of teaching to engineering students. Salary in accordance with the Burnham Scale for Lecturers in Technical Colleges, plus London allowance. The successful candidate will be expected to commence duties at the beginning of the summer term of 1954.

Details and forms of application may be obtained from the Principal, to whom completed applications should be sent within two weeks of the appearance of this advertisement. E5629

LONDON COUNTY COUNCIL

HANDICRAFT MASTERS

Applications invited from HANDICRAFT MASTERS recognised as qualified teachers for appointment to the Council's service (if not already in the permanent service) and assignment in January, 1954, to the following schools :—

Deansfield Centre, attached to Gordon Secondary, Craighton Road, Eltham, S.E.9 (metalwork).

Hither Green Secondary Boys, Beacon Road, S.E.13 (woodwork). Burnham (London) scale salary.

Apply at once to Headmaster on Form EO/TS40, obtainable from Education Officer (EO/TS4), County Hall, S.E.1 (send stamped, addressed, foolscap envelope). (1088.) E5597

LEYTONSTONE (No. 10) HOSPITAL GROUP

LANGTHORNE HOSPITAL, E.11

ASSISTANT ENGINEER

ASSISTANT ENGINEER required at Langthorne Hospital, E.11. The successful candidate will be immediately responsible to the Engineer-in-Charge in assisting with the operation of the engineering services, including both mechanical and electrical. Candidates must have completed an apprenticeship in mechanical engineering or by other means acquired a sound practical training in mechanical engineering, and, in addition, have undertaken a course of study in the technology of engineering. Applicants must also be in possession of an Ordinary National Certificate of Mechanical Engineering, which includes heat and heat engines as a subject, and preferably has an endorsement in the principles of electricity, or, alternatively, an approved equivalent qualification. It will be an advantage if applicants also possess a good knowledge of building and repair work. Salary scale £475 by £15 to £550 per annum, plus appropriate London weighting.—Application forms from the Group Secretary, Langthorne Hospital, E.11, to be returned by the 21st October. E5600

WESTMINSTER CITY COUNCIL

CITY ENGINEER AND SURVEYOR

Westminster City Council invites applications from gentlemen with appropriate professional or academic qualifications for the appointment of CITY ENGINEER AND SURVEYOR. Age limit 50 years. Salary, £2700 by £100 to £3000 per annum. J.N.C. conditions of service. Further particulars from Town Clerk, Westminster City Hall, Charing Cross Road, London, W.C.2, to whom applications should be sent before 2nd November, 1953. E5516

PUBLIC APPOINTMENTS

AIR MINISTRY

WORKS DEPARTMENT

MECHANICAL AND ELECTRICAL ENGINEERS

Air Ministry require MECHANICAL and ELECTRICAL ENGINEERS in Works Department for design, operation and maintenance of ground mechanical and electrical works services on R.A.F. stations at home and overseas and civil aviation stations. Appointments in two grades : (a) Main Grade, starting salary, £970, rising by eight annual increments to £1280 per annum ; (b) Assistant Grade, starting salary, age point, viz., age 25, £628 per annum, rising to £875 at age 34, thereafter rising annually to £970 per annum. Salaries somewhat lower in provinces. Appointments temporary and non-pensionable but with long-term possibilities. Special allowance up to £1300 a year according to location payable in addition to salary during overseas service. Candidates must be natural-born British subjects. Minimum qualifications and experience for both grades of posts : (i) (a) University Degree or equivalent Diploma in Electrical and/or Mechanical Engineering and at least a two-year apprenticeship or (b) Graduate or Corporate Membership of the Institutions of Mechanical or Electrical Engineers with appreciable electrical engineering experience and at least a three-year apprenticeship, and (ii) employment in responsible position for minimum of three years with well-established engineering concern providing wide experience in electrical and mechanical engineering practice.

Application forms, quoting Reference D/290/52A, from M.L. and N.S., Technical and Scientific Register (K), Almack House, 26, King Street, London, S.W.1. E5394

NATIONAL COAL BOARD

SCIENTIFIC TECHNICAL OFFICERS

National Coal Board invite applications for superannuable appointments as SCIENTIFIC TECHNICAL OFFICERS for metallurgical research at the Central Research Establishment, Isleworth, Middlesex. Good knowledge of metallurgical laboratory practice, including metallography, heat-treatment and mechanical testing is required. Knowledge of physical metallurgy and tool and structural steels and/or alloys would be an advantage.

Appointments, according to qualifications and experience, will be as either Scientific Technical Officers, Grade II (salary £485 by £20 to £705 per annum, male ; £390 by £16 to £566 per annum, female), or Scientific Technical Officers, Grade III (salary £375 by £20 to £535 per annum, male ; £300 by £16 to £428 per annum, female), plus London location allowance. Candidates should possess a Pass Degree in Metallurgy, A.I.M. (or equivalent), for S.T.O. II posts, and H.N.C. (Metallurgy) or L.I.M. for S.T.O. III posts.

Write, giving full particulars (in chronological order) of age, education, qualifications and experience (with dates), to National Coal Board, Establishments (Personnel), Hobart House, Grosvenor Place, London, S.W.1, marking envelope TT/689, and quoting this paper. Closing date 7th November, 1953. Original testimonials should not be forwarded. E5588

HER MAJESTY'S COLONIAL SERVICE

CHIEF MECHANICAL ENGINEER

Applications are invited for the following post :—CHIEF MECHANICAL ENGINEER, WORKS AND HYDRAULICS DEPARTMENT, TRINIDAD.

Duties of the post comprise responsibility for maintenance of fixed and construction plant and supervision of the departmental workshops.

Appointment is on contract for three years in first instance in the scale £1100 by £50 to £1200 per annum plus gratuity of £37 10s. for each completed three months' service on satisfactory termination of agreement. A varying cost-of-living allowance is also payable.

Free passages for the officer, wife and up to three children under the age of 18. Quarters are not provided, but allowance paid towards rent for private residence. Leave at the rate of 45 days a year.

Candidates must be Corporate Members or Graduates of the Institution of Mechanical Engineers or in possession of an Engineering Degree or Diploma recognised as granting exemption from Sections A and B of the A.M.I.Mech.E. examination. They should have had good experience of operation, repair and overhaul of construction plant, such as graders, scrapers, shovels and draglines.

Apply in writing to the Director of Recruitment, Colonial Office, Great Smith Street, London, S.W.1, giving briefly age, qualifications and experience. Mention the reference number CDE 112/38/04. E5563

BOROUGH OF TOTTENHAM

BOROUGH ENGINEER'S DEPARTMENT

SENIOR CIVIL ENGINEERING ASSISTANT

A vacancy exists for a SENIOR CIVIL ENGINEERING ASSISTANT (Established) at a salary of £670 p.a., rising to £735 p.a., or £710 p.a. rising to £785 p.a., i.e. Grade A.P.T. VI or VII of the National Scale of Salaries. London weighting allowance of £20 or £30 p.a., according to age.

Applicants must hold an appropriate final professional qualification and experience in structural engineering would be an advantage.

The Council are unable to offer housing accommodation.

Form of application and general conditions of appointment obtainable from the Borough Engineer, Town Hall, Tottenham, N.15, to whom applications must be delivered not later than Tuesday, 20th October, 1953.

M. LINDSAY TAYLOR,
Town Clerk.

E5623

PUBLIC APPOINTMENTS

SOUTHERN RHODESIA GOVERNMENT

CENTRAL MECHANICAL EQUIPMENT DEPARTMENT

Vacancies for Professional Mechanical Engineers and Technical Officers exist in the Central Mechanical Equipment Department, Southern Rhodesia Government.

SENIOR PROFESSIONAL OFFICERS, Grade III (four posts), £1794 by £72 to £1938 per annum.

Professional qualifications :

(a) Must be in possession of a University Degree in Mechanical Engineering or equivalent professional qualifications.

(b) Must have served a recognised apprenticeship in a mechanical engineering workshop or factory, preferably in connection with large-scale repairs to motor transport and heavy earth-moving plant.

(c) Must have had considerable experience in executive capacity as a professionally qualified mechanical engineer, especially in connection with the repair of heavy transport and earth-moving and construction plant.

(d) Must have a sound knowledge of metallurgy applied to the automobile and tractor industry.

(e) Must possess a sound knowledge and practical experience of modern methods of workshop control and management, time study, operational analysis, modern production methods and stores organisation and control.

(f) Drawing-office experience in connection with the repair or manufacture of automobiles or earth-moving plant an advantage.

SENIOR PROFESSIONAL OFFICER, Grade II (two posts), £1530 by £48 to £1722 per annum.

Professional qualifications :

(a) As for S.P.O. III.

(b) As for S.P.O. III.

(c) Must have had not less than five years' experience in an executive capacity as a professionally qualified mechanical engineer, preferably with a firm engaged in large-scale repairs of motor transport, earth-moving and construction equipment.

(d) Must possess a sound knowledge and practical experience of workshop organisation, management and control, also modern production methods and stores organisation and control.

(e) Drawing-office experience in connection with the repair or manufacture of automobiles or earth-moving plant an advantage.

JUNIOR PROFESSIONAL OFFICER (one post), £624 by £90 to £804 by £45 to £1074 by £30 to £1194 by £48 to £1482 per annum, actual starting point depending on qualifications and experience.

Professional qualifications :

(a) Must be in possession of a University Degree in Mechanical Engineering or equivalent professional qualifications.

(b) Subsequent practical experience on the repair of motor transport and earth-moving equipment an advantage.

(c) Drawing-office experience (mechanical) an advantage.

TECHNICAL OFFICERS, Grade I (two posts), £1194 by £48 to £1482 per annum.

Qualifications :

(a) Must have served a recognised apprenticeship in a mechanical engineering workshop or factory engaged on large-scale repairs or manufacture of automobiles or earth-moving plant.

(b) Must have had drawing-office experience in automobile or earth-moving plant design.

(c) Must have had experience of production progress, motion study, work simplification methods, job and operation analysis.

Generous leave conditions, low taxation, good climate.

Application forms and further details from the Secretary, Rhodesia House, 429, Strand, London, W.C.2. Completed forms to be returned by October 31st. E5585

MINISTRY OF WORKS

STRUCTURAL ENGINEERING DRAUGHTSMEN

STRUCTURAL ENGINEERING DRAUGHTSMEN required in London, at Risley (Warrington), Harwell (near Didcot, Berks.), Reading and Cambridge.

Accommodation available for single men at Risley and Harwell.

London salary : Up to £628 per annum. Starting pay according to age, qualifications and experience. Rates outside London slightly lower.

Applicants should be experienced in design and detailing of either reinforced concrete or structural steelwork. The work is varied and not confined to standard schemes.

Reasonable prospects of promotion. Although not established posts, many have long-term possibilities. Competitions are held periodically to fill established vacancies.

Write, stating age, nationality, experience and locality preferred, to Chief Structural Engineer, W.G.10/S.3 (K), Ministry of Works, Abell House, John Islip Street, London, S.W.1. E5611

MINISTRY OF FUEL AND POWER

SENIOR SCIENTIFIC OFFICERS AND SCIENTIFIC OFFICERS

Ministry of Fuel and Power require SENIOR SCIENTIFIC OFFICERS and SCIENTIFIC OFFICERS for the Chief Scientist's Division, London. Quals.: University Degree with First or Second-Class Honours in Scientific Subject (including Engineering) or equivalent. Knowledge of engineering and/or chemical thermodynamics advantageous. For S.S.O. posts candidates must be 28 years of age and should have at least three years' post-graduate experience. Duties concerned with conceiving and developing novel sources and uses of fuel and power. Inclusive salaries for 45½-hr. week S.S.O., £1161, S.O. £475–£877 (M.). Posts unestablished initially, but opportunity to compete for establishment may arise.—Application forms from M.L.N., Technical and Scientific Register (K), 26, King Street, London, S.W.1, quoting F.259/53A. E5587

THE ENGINEER

OCTOBER 9, 1953

Institution of Structural Engineers' Presidential Address

THE Institution of Structural Engineers' new president, Lieutenant-Colonel R. F. Galbraith, delivered his presidential address to the Institution on Thursday, October 1st. The address was entitled "Modern Development of Structural Engineering," and dealt successively with contemporary practice and developments in site investigation and soil mechanics, foundation work, structural theory, and with the various constructional materials commonly in use to-day. The concluding section of the address was concerned with future developments, and Colonel Galbraith mentioned some possible advances which he thought might find application in the future. It was hard to forecast the direction that technical developments would take, he said, but there were several apparent needs in the structural engineering world. Concrete which had a high crushing strength was a heavy material, and there was a demand for a light-weight concrete of high strength. If it could be produced at a competitive cost, the scope for its use in structural engineering was immense. The great defect of concrete, Colonel Galbraith maintained, mainly its high dead weight, would disappear and precast members could be increased in size without a comparative increase in the capacity of lifting tackle. He thought that perhaps the solution might be in the direction of hollow glass spheres, which had great crushing strength, cemented together with a silica gel. The strength of nylon thread had been exploited in the use of ropes for ship fitting, he noted, and he asked whether this strength could be used for structural purposes in the form of a non-corrosive reinforcement, whilst in a similar manner glass ropes and toughened sheet glass might become structural materials, he contended. In the field of plastics, materials were being developed which soon might be of use to the structural engineer, the speaker continued. The hardened resin and glass combination was an engineering material, the application of which had hardly yet been touched; it was about one-third the weight of steel, he said, and two-thirds the weight of aluminium, with a very high strength-to-weight ratio. Glass reinforced plastics had a high impact strength, he also noted, and were extremely resistant to corrosion. Another development which, in the president's opinion, was urgently needed was the extension of the education of the general contractor, his agents and work people in the use of modern techniques. The costs of building were extremely high, Colonel Galbraith remarked, and developments which might help to reduce costs should not be retarded by the lack of knowledge and experience of contractors.

Institution of Engineers and Shipbuilders in Scotland

SIR WILLIAM WALLACE, C.B.E., gave his presidential address to the Institution of Engineers and Shipbuilders in Scotland on Tuesday of this week, on the subject of "Survival at Sea." He recalled the "Titanic" disaster of 1912, in which so many lives were lost, due mainly to the lack of lifeboat capacity, and went on to mention that, as a result, new regulations required passenger ships to carry lifeboats capable of accommodating all on board. Further regulations had called for the provision of increased stability so that to provide the necessary lifeboats and associated equipment in addition to the requisite metacentric height had added considerably to the difficulties of the naval architect. Such problems, Sir William continued, suggested that the question of saving life at sea should be reconsidered in the light of progress made in design of light equipment used by aircraft. Aircraft carried inflatable rafts and lifebelts, and what logical argument, Sir William asked, could be used against the provision of similar equipment in ships, especially since an accident at sea generally allowed sufficient time for passengers to leave the ship, whereas in air travel, the time for leaving an aircraft was measured in minutes. Sir William went on to say that a sufficiency of lifeboat capacity did not ensure safety, since often the lifeboats on one side of a ship could not be launched due to a heavy list, and he instanced the recent loss of the "Princess Victoria." Lifeboats offered very little protection, whereas inflatable rafts of current design provided comparative comfort and recent tests had proved that personnel could survive in these craft even under arctic conditions. In place of lifeboats and other heavy top hamper, Sir William visualised the provision of two power-driven lifeboats, two emergency lifeboats and a sufficiency of inflatable equipment, and suggested a suitable method for launching the latter. Besides effecting a saving in weight, the fitting of inflatable life-saving gear would show a considerable saving in maintenance costs and in support of his suggestion that present regulations for saving life at sea should be reviewed, the president quoted several instances where rafts had proved their worth.

International Congress on Prestressed Concrete

DURING this week, the first international congress on prestressed concrete has been in progress in London. The congress was held by the International Federation of Prestressing, at the invitation of the Prestressed Concrete Development Group of the Cement and Concrete Association. A number of technical sessions were held at the Institution of Civil Engineers, on Tuesday, Wednesday and Thursday of this week, and various visits for members of the congress and their ladies were arranged. There was a Government reception for overseas delegates to the conference, and the Prestressed Concrete Development Group gave a dinner on Thursday evening. The technical matters discussed during the congress were limited to three specific topics, namely, the influence of abnormal temperatures on prestressed concrete construction; the design of statically determinate beams and slabs in prestressed concrete, based on ultimate load; and statically indeterminate structures in the plastic and elastic states. No contributions on the first of these subjects were received from the Continental countries, and the basis of the general report, which was presented by Mr. A. W. Hill, was the work carried out at the Fire Research Station at Elstree, under the British Standard test conditions. The general report on the second topic was prepared by Professor Magnel, from five papers in which alternative design methods were given. The various formulæ were compared graphically with test results, and it was noted that they gave very similar results and all of them were only reliable for steel contents of up to 6 per cent. A great deal of interest is being shown in the design of statically indeterminate structures. The third general reporter, Monsieur Y. Guyon, noted that the papers in his section reflected the universal interest and particular difficulties of continuity in prestressed concrete, and a considerable diversity of views was represented by contributions to the congress which were concerned with that subject.

Engineering Services in the Coal Industry

THE National Coal Board's engineering department in London has collected a great deal of information on workshop design and, for the guidance of engineering staffs in the coalfields, has produced designs for area and colliery workshops embodying the most modern practice. The first area workshop based on these designs is to be in the Scottish Division and it is stated that the principles used are being incorporated into several existing workshops in other divisions. It will be recalled that in the *Plan for Coal* the Board set out its workshop policy and stated that expenditure on central workshops up to 1965 would be about £11,300,000 (on 1949 values). In the organisation of its engineering services, the Board intends that colliery workshops shall provide a service designed to prevent the breakdown of colliery plant and equipment by a system of planned, preventive maintenance and first-aid repairs. Wherever possible men and machines from colliery shops will be transferred to the area central workshop. The central workshop will provide another planned and organised system for the reconditioning of plant and equipment at regular intervals, and there will be trained mobile gangs to supplement colliery resources when necessary. "Unserviceable" parts and materials will be salvaged for reissue and further use, and there is to be a centre at which defects and modifications in equipment and plant can be investigated as a normal routine on their passage through the central shops for overhaul. But, the Board has stated, the main function of central workshops is the reconditioning of equipment, and a modern central workshop must be able to compete in cost and speed with anything obtainable outside the industry. To achieve this, the workshop must be laid out on modern lines, it being necessary to ensure that jobs on their way through the workshop follow a progressive forward motion as far as possible. Thought has been given to the provision of training facilities, not only for apprentices, but for the rest of the workshop staff so that they may benefit from the introduction of new ideas and procedure and learn the details of the new equipment introduced into the industry. The Coal Board's recommended designs for workshops, will be applied first at the new Cynheidre Colliery in the anthracite coalfield of South Wales.

A Bearing Factory in County Durham

ON Friday, October 2nd, the parliamentary secretary to the Ministry of Supply, Mr. A. R. W. Low, officially opened a new factory built for the Ransome and Marles Bearing Company, Ltd., at Annfield Plain, County Durham. The factory is sited in an area scheduled for industrial development, for the end of the useful life of various collieries in the area can be foreseen and, as Mr. Low remarked, the establishment of other industries is being encouraged. The bearing factory has an area of about 100,000 square feet, and will employ 600 or 700 persons when it is in full production, which is expected to be during next year. It will manufacture bearings for balls of 1in maximum size, and all the manufacturing and assembly processes will be carried out in the factory, except for the manufacture of the balls and rollers themselves, which will be brought from one of the other factories of the firm. About a third of the ultimate full complement of workers are at present employed in the factory. The inner and outer housings of the bearings are made from tube stock, a number of six-spindle automatic lathes, arranged to produce two housings in each machine cycle, being installed for the principal machining operations. Gas-heated atmosphere-controlled furnaces are installed for heat-treatment of the housings. Finish grinding is carried out on centreless grinders, the various processes of finishing and assembly being carried out in a second shop. At a luncheon held at the time of the opening, Mr. Low and Lord Lawson, Lord Lieutenant of the County of Durham, both spoke of the encouragement to the area offered by the new industry. Mr. Richardson and Mr. Senior, the managing director and chairman, respectively, of Ransome and Marles, also spoke.

A Short History of Spectroscopy

By T. W. CHALMERS, D.Sc., M.I.Mech.E.

No. X—ENERGY DISTRIBUTION IN THE SPECTRUM

(*Concluded from page 419, October 2nd*)

THE problem which physicists had to face at the end of the nineteenth century consisted of finding a rational expression for the form of the energy distribution curves given in Fig. 29 *ante*.

Their approach to the problem was governed by certain clear requirements :

(1) The expression had to be *rational*—that is to say, it had to be deducible from the known general principles of physical science and not merely an empirical fitting of a mathematical equation to the curves.

(2) Whatever might be the expression at which they arrived the area under the curve which it represented must be in harmony with Stefan's law of total black body radiation $I=\sigma T^4$. We may recall that I here stands for the energy emitted per second per square centimetre of its surface by a "black body" at an absolute temperature T. Strictly speaking I should therefore be referred to not as "energy" but as "intensity of energy."

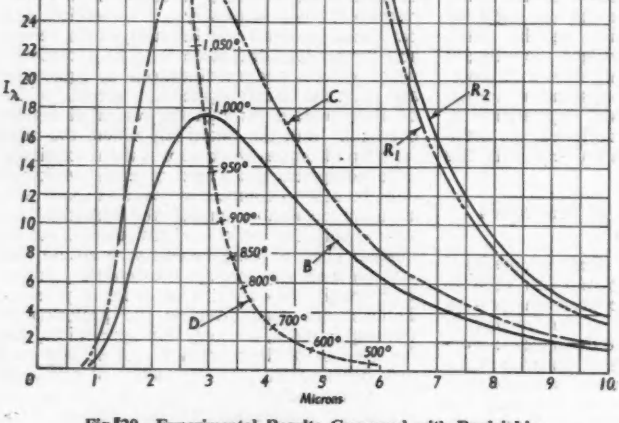


Fig. 30—Experimental Results Compared with Rayleigh's Formula for Energy Distribution

(3) The expression should show a maximum value of the emitted intensity of energy and that maximum value should be associated with a finite wavelength λ_m conforming with Wien's displacement law, $\lambda_m T=A$ (const.)

(4) At the maximum point, the intensity of the energy should harmonise with Wien's second deduction, namely, $I_m=CT^5$.

(5) From (3) and (4) the relationship $I_m=FT/\lambda_m{}^4$ ought to hold good.

The problem thus set engaged the attention of many leading mathematical physicists. There can be little doubt that they were not only intrigued by it academically, but that instinctively they felt that it contained something which was of portentous fundamental significance.

It is convenient, although not strictly accurate chronologically, to consider first Lord Rayleigh's solution of the problem. Working rigorously in accordance with the established principles of classical mechanics, Rayleigh concluded that the energy in the spectrum ought to be distributed among the wavelengths in accordance with the relationship

$$I_\lambda=8\pi kT/\lambda^4 \quad . \quad . \quad . \quad . \quad . \quad (6)$$

Others, including Jeans, following various arguments differing in detail, but always adhering to classical mechanics, confirmed this result and physicists were forced to confess that classical mechanics could yield no other.

Nevertheless, Rayleigh's formula was quite inacceptable. In Fig. 30 the curves marked R_1 and R_2 are those given by it for $T=1000$ deg. Cent. and 1100 deg. Cent. respectively. The curves given by experiment at those temperatures are shown at B and C. Curve D is the locus of the maximum points of the experimental curves.

It will be seen that Rayleigh's curves agree with the experimental in only two respects : (1) as the wavelength increases towards infinity they show that the energy trends downwards towards zero, and (2) a rise of temperature shifts the curve upwards, although to a lesser extent than the experiments require.

The most notable fact about the Rayleigh curves is, however, their complete failure to show any sign of a maximum. Their implication is that as the wavelength shortens the energy should increase without interruption. At zero wavelength the energy ought to be infinitely great, a conclusion irreconcilable with both common sense and experimental observation.

Thus in his attempt to fulfil the first requirement, that of rationality as judged by accepted mechanical principles, Rayleigh was led to a result totally out of keeping with the requirements which we have numbered (2) to (5) above.

From the predicament thus revealed there seemed to be only one means of escape, namely, to fulfil the requirements (2) to (5) at the expense of abandoning the first—that is to say, to harmonise theory with experimental fact, even although the theory could not be strictly justified as "rational" in the light of orthodox mechanical doctrine.

One such attempt was made by Wien. Making some arbitrary assumptions he produced an energy distribution formula of the form,

$$I_\lambda=\frac{P}{\lambda^5 . e^{p/\lambda T}} \quad . \quad . \quad . \quad . \quad (7)$$

where P and p are constants. At first sight, this formula seems to bear little relation to Rayleigh's, but closer examination reveals a certain connection between them. Let us write $p/\lambda T=x$, that is, $1/\lambda=Tx/p$. Then Wien's formula becomes

$$I_\lambda=\frac{P}{p}\cdot\frac{T}{\lambda^4}\cdot\frac{x}{e^x} \quad . \quad . \quad . \quad . \quad (8)$$

It is thus seen to be Rayleigh's formula multiplied by a factor $x/e^x=Z$ (say), a pure numeric.

A little study shows that the factor Z is zero if x is zero and again zero if x is infinitely great. Intermediately Z rises to a maximum of 0·3679, when x is unity. Calculating the value of Z for other values of x and plotting the results, we get the curve shown in Fig. 31.

The effect of multiplying Rayleigh's formula by the factor Z will clearly be to introduce a maximum into it by causing it to bend downwards at the start from infinity to zero and in the later portion, after the maximum, to allow the trend towards zero at very long wavelengths to remain.*

The introduction of the factor Z into the Rayleigh formula thus converts the curves R in Fig. 30 into a form which will be at least reasonably like the experimental curves B and C in so far that they will now have defined maxima and will not go trailing off

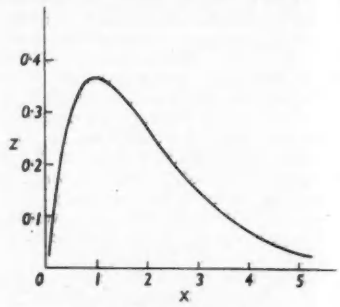


Fig. 31—The Factor Z

to infinity at zero wavelength. The question remains : Does the introduction of Z produce harmony with the practical requirements (2) to (5) ?

Mathematical analysis shows that it does do so. Filling in the value of $x(=p/\lambda T$ we can at once derive from (8) the value of λ (say, λ_m), at which the energy is a maximum. Differentiating with respect to λ and regarding T as constant, we find that the energy I_λ emitted per second per square centimetre of the surface of the "black body" is a maximum for a wavelength given by

$$\lambda_m T=p/5 \quad . \quad . \quad . \quad . \quad (9)$$

and that the maximum amount of the energy, which is associated with this wavelength, is

$$I_m=20{\cdot}94\frac{P}{p^5}\cdot T^5 \quad . \quad . \quad . \quad (10)$$

These two results fulfil the requirements (3) and (4) respectively, and from them we can calculate that

$$I_m=0{\cdot}033\frac{P}{p}\frac{T}{\lambda_m{}^4} \quad . \quad . \quad . \quad . \quad (11)$$

which fulfils requirement (5).

As for requirement (2) we find by integration that the area under Wien's curve taken from $\lambda=0$ to $\lambda=$infinity—or the total energy radiated at all wavelengths—is given by

$$I_{(total)}=\frac{6P}{p^4}\cdot T^4 \quad . \quad . \quad . \quad . \quad (12)$$

which harmonises with Stefan's law.†

We can thus assert that Wien's formula satisfies the practical requirements (2) to (5). The curve which it yields agrees closely—or, by suitable choice of the constants P and p, can be made to agree closely—with the experimental curves.

At the same time, the assumptions which Wien made in evolving it could not be regarded as fulfilling the requirement (1)

* It is necessary to note that in Fig. 31 $x=p/\lambda T$. Hence, $x=0$ corresponds to an infinitely long wavelength and $x=$ infinity to zero wavelength. The horizontal scales in Figs. 30 and 31 therefore, in terms of wavelength, run in opposite directions.

† If Wien's formula is rewritten as

$$I_\lambda=(P\lambda^{-5}T/p)(\lambda^{-1}e^{-p/\lambda T}{}_{p/T}),$$

it becomes amenable to successive integration by parts. The general integral is a four-term expression which evaluated between the limits $\lambda=0$ and $\lambda=\infty$ yields the result given at (12).

of "rationality." That they involved an irrationality was first pointed out by Rayleigh. In equation (7), if T is made infinitely great the factor $e^{ρ/λT}$ for any value of $λ$ becomes equal to unity. Therefore, according to the formula, the energy emitted at any wavelength ought, as the temperature of the "black body" is raised higher and higher, to approach a *finite* limiting value of $P/λ^5$. This result was regarded as "improbable." In practical terms it would mean that as the temperature of a body was raised a point would ultimately be reached at which farther increase of temperature would fail to increase the energy content of the radiation. No result had ever been recorded in practice which suggested that the energy emitted by a heated body did not increase indefinitely with increase of temperature.

It might, of course, be objected in opposition to Rayleigh's contention that practical experience was too restricted, that we had necessarily been confined to observations made at finite temperatures and that there was no telling what would happen at temperatures beyond practical realisation. Nevertheless, it was felt that in spite of its very considerable success in reproducing the form of the experimental energy distribution curves Wien's formula did not provide the last word on the subject. It seemed to demand modification in some way which would fulfil yet another requirement, namely, (6). The formula ought to involve the temperature T in such a way that the energy $I_λ$ ought to increase indefinitely with increase of the temperature towards infinity.

The practical significance of this requirement can be gathered from Fig. 29. If we select a particular wavelength—say, 3 microns—we see that as the temperature is increased the curves get farther and farther apart. The diagram indicates the following approximate results :—

$λ=3μ$

Temperature	Energy	Increase of energy per deg. T
998	11	
		0·062
1095	17	
		0·085
1259	31	
		0·126
1449	55	
		0·152
1646	87	

The range of temperature is not very great, but such as it is the curves clearly imply that the energy emitted increases more than proportionately with the temperature. It would be improbable if at still higher temperatures this increase of energy per degree of temperature rise slowed down and became constant.

In 1900 Professor Max Planck, of Berlin, introduced a new formula for the distribution of energy in the spectrum emitted by a "black body." Many confusing explanations have been published regarding the manner in which Planck was led to his formula. The simplest and the most correct is that it was the product of a straightforward attempt to combine Wien's and Rayleigh's formulæ in such a way as to eliminate the flaws in each. He groped his way towards it and then having found it evolved a theory to account for it. The formula was not deduced from the theory. The theory was made to fit the formula. This is the reverse of the process usually followed in physical studies.

The formula at which Planck arrived was

$$I_λ=\frac{Q}{λ^5(e^{q/λT}-1)} \quad . \quad . \quad . \quad (13)$$

where Q and q are constants. Let us write $q/λT=x$. Then (13) becomes

$$I_λ=\frac{Q}{q}\cdot\frac{T}{λ^4}\cdot\frac{x}{(e^x-1)} \quad . \quad . \quad . \quad (14)$$

It is thus seen to be Rayleigh's formula multiplied by a factor $\frac{x}{e^x-1}=Y$, say. At (8) we saw that Wien's formula was Rayleigh's multiplied by a factor $Z=x/e^x$. Thus, Planck's formula did no more than introduce -1 into the denominator of Wien's factor Z.

Never before, we can well believe, in the whole history of physical science have such profound consequences flowed from such a simple addition as this -1. It led to a revolution in classical mechanics. In his efforts to explain his formula Planck was ultimately induced to evolve the quantum theory according to which energy is not infinitely divisible as the Newtonians had tacitly supposed, but always existed in ultimate parcels of finite amount.

Thus, at the start of the nineteenth century physicists under Dalton's inspiration had been forced to the conclusion that matter consisted of particles of finite size. Near its end J. J. Thomson had shown them that electricity was also granular. Now, in the very last year of the century, Planck had arisen to teach them that energy was likewise restricted to ultimate bundles of finite amount.

Performance and Efficiency Tests on S.R. Diesel Electric Locomotive

By O. S. NOCK, B.Sc., M.I.C.E., M.I.Mech.E.

No. II—(*Concluded from page 427, October 2nd*)

In a previous article the author discussed the results of analytical tests described in the latest test bulletin issued by the Railway Executive. In this concluding article reference is made to the dynamometer car trials conducted with locomotive No. 10202 *on ordinary service trains, and to some runs in regular working when no special tests were in progress.*

THE service tests were made on the 7.30 a.m. express passenger train from Exeter Central to Waterloo, and on the 1 p.m. from Waterloo to Exeter. Both these trains convey relatively heavy loads over lengthy parts of their journeys and the schedules include a number of intermediate stops. The section of line between Salisbury and Exeter is heavily graded, and includes the especially severe ascents to Honiton tunnel. The alignment of the road throughout is, however, very good, and high speeds can be run on the descending gradients. On non-stop runs between Salisbury and Exeter maximum speeds between 80 and 90 m.p.h. are regularly attained at five or six points on the journey and impetus from such speeds is utilised to climb the succeeding steep gradients. In the years immediately preceding the second world war it was not unusual for Maunsell two-cylinder 4–6–0s of the "King Arthur" class to work trains of thirteen or even fourteen bogie coaches from Salisbury to Exeter non-stop at average speeds of 57 to 58 m.p.h. start to stop.

But the Exeter road becomes another matter altogether when a number of intermediate stops are scheduled, as with the 7.30 a.m. up train especially, when some of these stops, as at Axminster, Sherborne and Gillingham are at stations lying at the foot of severe gradients. The gradient profile of the line between Salisbury and Exeter is shown in Fig. 9. East of Salisbury the grading is more even, though the long, adverse stretch from Weybridge westwards to Oakley can provide a severe tax upon a locomotive in adverse conditions. The various start-to-stop runs operated west of Salisbury on the test journeys were as in Tables III and IV overleaf.

On the eastbound runs eight vehicles were

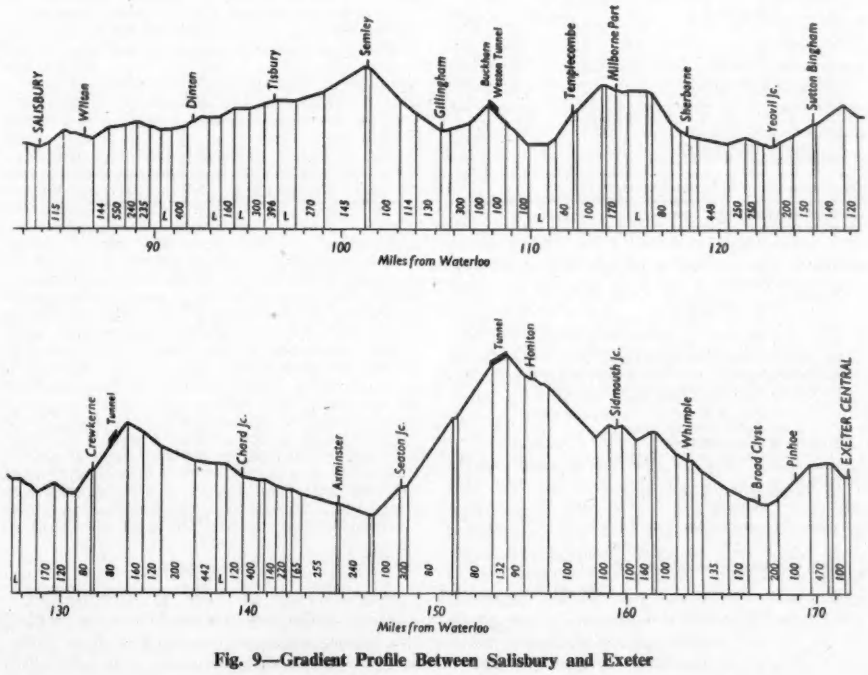


Fig. 9—Gradient Profile Between Salisbury and Exeter

taken on each journey, about 266 tons tare. On the westbound runs the loads between Salisbury and Templecombe were twelve vehicles on one trip and thirteen on the second, while the continuation loads from Templecombe were nine and eight vehicles, respectively. Studying the time schedules in relation to the gradients and loads it will be appreciated that the locomotive was set a fairly stiff task. Very good time was kept between Salisbury and Exeter. On one journey when the start from Yeovil was 8½ min late, due to temporary speed restrictions earlier in the run, the 48·9 miles to Exeter were covered in 44 min start to stop, instead of the 56 min booked, though, of course, a longer run of this kind would give time for the speed capabilities of the locomotive to be fully developed. The summarised results of the four service trials are given in Table V.

TABLE III—*Westbound*

Section	Distance, miles	Booked time, min.	Average speed, m.p.h.
Salisbury-Templecombe ...	28·4	34	50·1
Templecombe-Sherborne ...	6·1	11	33·3
Sherborne-Yeovil Junction	4·6	8	34·5
Yeovil Junction-Exeter ...	48·9	56	52·4

TABLE IV—*Eastbound*

Section	Distance, miles	Booked time, min.	Average speed, m.p.h.
Exeter-Sidmouth Junction ...	12·2	16	45·8
Sidmouth Junction-Axminster	14·8	18	49·3
Axminster-Yeovil Junction	21·9	25	52·5
Yeovil Junction-Sherborne	4·6	7	39·4
Sherborne-Templecombe ...	6·1	10	36·6
Templecombe-Gillingham ...	6·8	9	45·3
Gillingham-Salisbury	21·6	25	51·8

In order to maintain the schedule times laid down the locomotive had to be worked in Notch 8 for most of the time that a measurable force was being exerted on the drawbar. On the test with the 1 p.m. down train on April 28th the locomotive was worked in Notch 8 for 75 per cent of the time under power. If reference is made to Fig. 6 in the preceding article, which shows the efficiency with which the fuel is utilised, it will be seen that the locomotive was working to the best advantage, a fact that is reflected in the average thermal efficiencies recorded on these service tests.

In the test bulletin an interesting connection between the service trials and the analytical tests is shown in a diagram reproduced in Fig. 10. Lines are drawn on this diagram joining the 20 per cent efficiency points in Notches 6, 7 and 8 for weak, intermediate and full fields. The actual test results from the "service" runs are also plotted and they lie slightly below the "weak field" line. With the drawbar tractive effort characteristics established, and relying on the consistency of performance, day in, day out, that is inherent in a diesel-electric locomotive, time schedules can be arranged so as to use the machine at its optimum efficiency throughout. Difficulty arises, however, if the trailing load of any such train is liable to weekly or seasonal fluctuation; then one is faced with the alternatives :—

(*a*) Providing extra power to meet such peak loads and running in normal times at a lower overall efficiency.

(*b*) Providing suitable power for normal times and reducing the margin for recovery at times of peak loading.

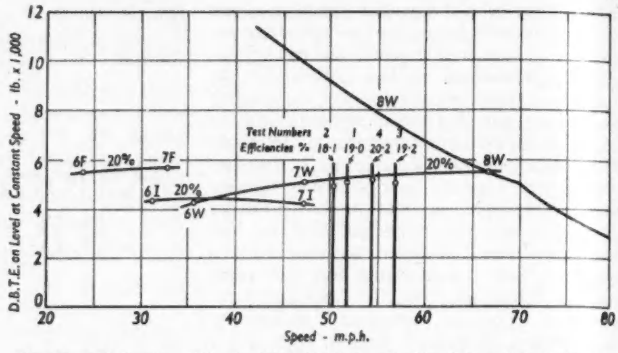


Fig. 10—Efficiencies of Service Tests Plotted on to Graph from Fig. 2 (No. I)

These alternatives are typical of the compromises often necessary in the provision of railway motive power, between the theoretical ideal, and the practical necessities for good working.

When the author was privileged to travel in the cab of locomotive No. 10202 on the 1 p.m. down express from Waterloo the load was considerably heavier than any recorded in the dynamometer-car trials covered by Table V: fourteen vehicles, weighing 466 tons tare. Moreover, this journey was made at a summer holiday week-end with the train crowded; it is estimated that the gross load behind the locomotive was approximately 500 tons. The time schedule of the train between Waterloo and Salisbury is :—

TABLE VI

Distance, miles		Time, min.	Average speed, m.p.h.
0·0	Waterloo	0	—
3·9	Clapham Junction	7	33·4
13·3	Hampton Court Junction...	18	51·2
24·4	Woking	29	60·6
0·0		0	
25·9	Worting Junction	29	53·6
42·0	Andover Junction	45	60·4
0·0		0	
16·3	Tunnel Junction	18½	52·9
17·4	Salisbury	21	26·4

Underlined distances and times refer to stopping places.

During the period of the service tests with the dynamometer car temporary speed restrictions were in force between Hampton Court Junction and Woking, and again between Andover and Tunnel Junction. These prevented strict time-keeping over these sections. But between Woking and Andover the time was 43 min on both April 28, 1952, with a trailing load of 397 tons tare, and on April 30th, when the tare load was 432 tons.

On the ordinary service run, with a load of 466 tons tare, 500 tons gross behind the locomotive, Notch 8 was used throughout from Waterloo to Weybridge—apart from a brief easing through Clapham Junction. The second timing point, Hampton Court Junction, was passed slightly ahead of schedule in 17½ min from Waterloo,

TABLE V

Trains: Down 1 p.m. ex-Waterloo to Exeter Central, stopping at Woking, Andover Junction, Salisbury, Templecombe, Sherborne and Yeovil Junction. Up: 7.30 a.m. ex-Exeter Central to Waterloo, stopping at Sidmouth Junction, Axminster, Yeovil Junction, Sherborne, Templecombe, Gillingham, Salisbury and Andover Junction.

Test No.	1	2	3*	4
Date	April 28, 1952	April 29, 1952	April 30, 1952	May 1, 1952
Direction	Down	Up	Down	Up
Load :				
Waterloo to Templecombe (Tare, tons)	397 for 12 vehicles		432 for 13 vehicles	
Templecombe to Exeter Central (Tare, tons)	299 for 9 vehicles		265 for 8 vehicles	
Exeter Central to Salisbury (Tare, tons)		266 for 8 vehicles		267 for 8 vehicles
Salisbury to Waterloo (Tare, tons)		362 for 11 vehicles		398 for 12 vehicles
Distance :				
Actual (Miles)	171·4	171·4	147·1	171·4
Under power (Miles)	157·7	148·5	137·7	151·9
Ton miles (excluding locomotive)	62,200	53,600	53,600	56,700
Time :				
Booked :				
Overall (Minutes)	222	218	191	218
Running (Minutes)	204	202	175	202
Actual :				
Overall (Minutes)	221·5	225	182·6	219·3
Running (Minutes)	204·7	208·1	163·6	197·3
Standing at stations (Minutes)	16·8	16·9	19·0	22·0
Under power (Minutes)	182·4	176·8	147·9	167·7
Drifting and braking (Minutes)	22·3	31·3	15·7	29·6
Average speed :				
On running time (M.p.h.)	50·2	49·4	54·0	52·1
On time under power (M.p.h.)	51·8	50·3	56·8	54·4
Work done (Drawbar horsepower hours)	2,114	1,953	1,855	2,125
Average drawbar horsepower	695	663	753	761
Average drawbar pull (Tons)	2·24	2·20	2·26	2·34
Oil :				
Gross calorific value (B.Th.U. per pound)	19,550	19,550	19,530	19,540
Total used (Pound)	1,481	1,430	1,281	1,400
Average rate on overall time (Pounds per hour)	401	381	421	384
Used under power (Pounds)	1,450	1,390	1,251	1,358
Rate under power (Pounds per hour)	477	472	508	486
Used whilst drifting and braking (Pounds)	18	27	13	24
Rate whilst drifting and braking(Pounds per hour)	48·5	51·7	49·7	48·6
Used whilst standing at stations (Pounds)	13	13	17	18
Rate whilst standing at stations (Pounds per hour)	47·4	46·1	53·7	49·1
Pounds per drawbar horsepower hour on total fuel used	0·700	0·732	0·69	0·659
Pounds per drawbar horsepower hour under power	0·686	0·711	0·675	0·639
Pounds per mile on total fuel used	8·64	8·34	8·71	8·17
Pounds per mile under power	9·20	9·37	9·10	8·95
Pounds per ton mile on total fuel used	0·0238	0·0267	0·0239	0·0247
Efficiencies :				
$\frac{\text{Heat equivalent of work done at drawbar}}{\text{Total oil used} \times \text{gross calorific value}} \times 100$ per cent	18·6	17·6	18·7	19·6
$\frac{\text{Heat equivalent of work done at drawbar}}{\text{Oil used under power} \times \text{gross calorific value}} \times 100$ per cent	19·0	18·1	19·2	20·2

* Late arrival on train at Waterloo due to repair of a minor mechanical defect on locomotive.
Test connections made at first stop at Woking from which point test commenced

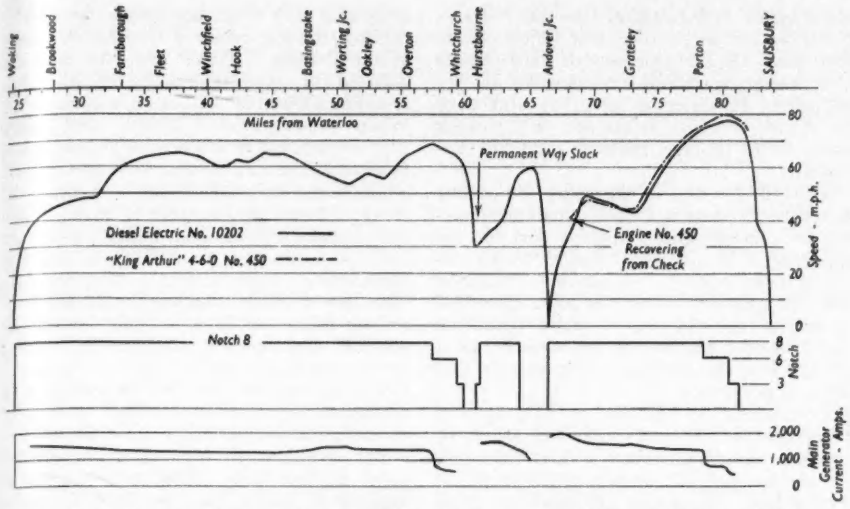


Fig. 11—Performance of Locomotive No. 10202 on the 1 p.m. Express from Waterloo to Salisbury

but a stop for adverse signals at Byfleet caused a late arrival of 2½ min at Woking. From this point the performance westwards to Salisbury is shown in diagrammatic form. It will be seen that the locomotive was worked at full capacity until Overton, but that one minute was lost between Woking and Worting Junction without any delays. The field currents have also been plotted, and they correspond very closely to those shown on the diagrams in the bulletins. Between Andover and Salisbury, where Notch 8 was used until speed had reached 75 m.p.h. on the descent of Porton Bank, a further minute was dropped on booked time—no delays being experienced, so that the limit of the locomotive capacity had been reached. There was, of course, no margin for any recovery of time lost earlier

TABLE VII—*Diesel-Electric Locomotive No.* 10202 : *Load* 265 *tons*

Distance, miles		Time, min. sec.	Average speed, m.p.h.
0·0	Andover	0 00	—
3·8	Milepost 62½	5 43	39·9
5·3	Hurstbourne	7 08	63·6
7·2	Whitchurch	8 52	65·5
10·8	Overton	11 53	71·7
14·0	Oakley	14 27	74·7
16·1	Worting Junction	16 07	75·7
18·6	Basingstoke	17 56	82·7
24·2	Hook	21 50	86·1
29·9	Fleet	25 48	86·0
33·2	Farnborough	28 07	85·5
38·4	Brookwood	31 58	81·1
42·0	Woking	34 37	81·5
47·3	Weybridge	38 23	84·5
53·1	Hampton Court Junction...	43 02	74·8
54·4	Surbiton	44 14	Eased
		p.w. slack	15 m.p.h.
62·5	Clapham Junction	53 48	signal
66·4	Waterloo	61 51	checks

and the train reached Salisbury 8 min late. Superimposed upon the speed diagram between Andover and Salisbury is the performance of a class "5" steam passenger locomotive of the "King Arthur" class, hauling a load of 450 tons behind the tender. The speed was slightly higher than that of the diesel between Red Post Junction and Grateley, on the adverse gradient; subsequent acceleration was faster and the final maximum speed nearly 80 m.p.h.

On the author's journey with locomotive No. 10202, made three months after the dynamometer car tests with service trains, the driver and fireman were in sole charge. No running inspector, nor other personnel were riding. The enginemen were from Salisbury depot and worked the diesel locomotive as part of their ordinary duties, the majority of which were steam worked. The locomotive rode extremely well at all speeds, though the excellence of the permanent way and the relative straightness of the line itself no doubt made some contribution to the smooth and pleasant travelling that characterised the journey.

The capacity of the locomotive for high speed with the original gear ratio is shown by details of an eastbound journey with a relatively light load when an accelerated schedule was temporarily in force. In Table VII are shown details of the times made, with the average speeds alongside. Comparison can be made with the gradient profile in the performance diagram of the heavy-load trip with the 1 p.m. down express, and the nature of the high-speed performance on the eastbound will be better appreciated.

Referring to the gradient profile, it will be noted that on the rising stretch between Whitchurch and Oakley speed averaged well over 70 m.p.h., while on the favourable length between Worting Junction and Weybridge the average was 84·2 m.p.h. These details were made available to me by a fully experienced recorder who was travelling as a passenger in the train, and so, unfortunately, no details of the engine working are included in the recorded "log." But the run shows how very suitable these Southern diesels are for sustained high-speed running with relatively light trains.

Institution of Naval Architects

No. III—(*Concluded from page* 424, *October* 2*nd*)

THE Autumn meeting was continued on the morning of Wednesday, September 16th, under the chairmanship of Sir Stanley V. Goodall, with the reading of the following paper :—

ON PROPELLER MANUFACTURE

(With special reference to planing of the blades and dimensional accuracy)

BY PROFESSOR L. C. BURRILL, M.Sc., Ph.D.

SYNOPSIS

During the past twenty-five years there have been considerable changes in the design of marine propeller blades. Merchant ship propellers now have a variable pitch from root to tip, the shape of the blade sections varies from radius to radius, and it is common to find that while the inner blade-sections have a rounded or positively cambered face, the outer sections will have a flat face, or even have a hollow or negatively cambered face.

These changes in design have arisen from advances in propeller theory and from the general application of "aerofoil" sections to marine propellers. The adoption of these sections has led to a change of attitude towards the degree of precision with which the blades of marine propellers require to be defined and finished.

When propellers had blade sections of segmental type with a flat driving face and rounded back, attention was focused mainly on accuracy of face-pitch. The study of the performance of aerofoils in wind tunnels has led to an appreciation of the importance of precise streamline shape and also of the fact that the back of the blades is responsible for by far the greater part of the work done. By meeting the rise in engine powers and revolutions and the demand for high efficiency by augmenting the local suctions on the back of the blades, methods of definition and measurement, adequate for propellers carrying light loading, have proved to be inadequate with the higher suction loadings now accepted, because an error in blade section shape can have serious consequences in the form of cavitation erosion, vibration and noise.

Improvements in design technique have called for improved methods of manufacture. There has been the introduction of the sand-cement process for the construction of propeller moulds, giving improved rigidity and more accurate initial propeller castings. There are new machines enabling the whole pitch face of the blades to be planed with a single-point tool to a uniform or variable pitch, and new and improved instruments for marking off and measuring the blades. A list of standard tolerances is quoted.

DISCUSSION

Professor Dr. Ir. W. P. A. van Lammeren : This paper is of interest to propeller manufacturers and designers and demonstrates the difficulties in producing propellers of modern design, especially if they machine the faces of the blades by means of a planing tool. Although a modification of a complicated pitch distribution curve may be allowed to enable the propeller maker to simplify the manufacture of the casting, I am sure that this will not be possible in most instances of wake-adapted propellers designed in accordance with the latest development of the vortex theory. In general, the curve of pitch distribution for this kind of propeller will differ from that given in Fig. 8 of the paper.

There will be a considerable saving of time and labour costs when the procedure in Section 6 is applied, but does the author consider this procedure, using sweeping board and double pitch rail, to be so accurate that no correction of the mould will be necessary afterwards?

Some years ago we started the standardisation of tolerances on propeller dimensions in Holland, and the results have been laid down in a standard list, which has been adopted by the technical committee concerned of the International Standardisation Organisation, ISO/TC 8, at the International Conference held in Holland in November, 1952.

When comparing this standard list with that given by the author there appears to be good agreement for the class of propellers considered, so that there is a basis on which agreement should be possible between the prescriptions given by the ISO/TC 8 and those used in Great Britain. In Table II, it is peculiar to see that the tolerances for propellers of different sizes are given in different units, and in my opinion this is most confusing.

The author states that he prefers to define blade sections parallel to the shaft centre line, and not perpendicular to the blade face. I can agree with him ; but Fig. 12 gives the impression that the blade thickness is being measured perpendicular to the blade face. It will always be difficult to measure blade thickness parallel to the shaft centre line when using engineers' calipers, especially with propellers having a fair rake.

The last page of the paper deals with static

and dynamic balancing, and I endorse the author's views that dynamic balancing need not be considered for accurately made propellers. As to the static balancing, the amounts of the weights added to the tips of the blades cannot be absolute values. They depend on the sensitivity of the balancing apparatus.

Mr. V. G. Shepheard : It is re-assuring to have such an account of the progress in propeller manufacture and the care taken to ensure that the propellers are fully in accordance with the intentions of the designers.

Professor Burrill states that the impetus for precision arose from the greater concentration of the designer to ensure high propeller efficiency under heavier loading and to avoid the pitfalls of erosion, vibration and noise. This has resulted in a wide use of aerofoil sections in merchant ship propellers, and this has played its part in the urge for precision.

Some years ago differences were found in the dimensions of propellers, of certain warships, made to the same drawing. The differences were small and hardly likely to be significant from a propulsion point of view, but they were sufficient to give rise to objectionable variations in other qualities. It was evident from this experience that a more detailed specification of finish and manufacturing tolerances was called for. While requirements have been revised in the light of experience, including the desirability for avoiding unnecessary complication in propeller manufacture. It is therefore emphasised that, for warship propellers, precision standards are essential for all types, and not peculiarly for propellers with aerofoil sections.

The information on tolerances given in the paper indicates the high standards attained in the manufacture of what is undoubtedly a complicated product. It appears that the standards mentioned are consistently obtained, and this is taken to mean that all propellers, irrespective of design are finished to or within the standards mentioned, according to size. The thought arises that the improved methods of casting and machining could also promote quicker production than was possible by the older methods.

Professor Ir. H. E. Jaeger : I want to make a plea, as Chairman of ISO/TC 8, for international standardisation in general in shipbuilding. So far we have had two meetings of that committee and on both occasions the British were absent. To be a truly international organisation in shipbuilding it is necessary for Great Britain to play a part for I know that in Great Britain you are not unmindful of the importance of standardisation and I have the greatest respect for the British Standards Institution. In the standardisation of propellers we have done some good work and I hope that when the I.S.O. committee meets in 1956 or 1957 a British delegation will be there.

Dr. R. W. L. Gawn : As far as I can recollect, the subject has not been dealt with previously in our *Transactions* and we are fortunate that Professor Burrill is in a position to tell us about the processes of manufacture and the degree to which the finished product complies with the requirements of the designer. The accuracy of finish quoted should satisfy the most exacting, but I noted that no reference was made to root fillets. I have noted propellers in which both the leading and the trailing edges at the roots were finished very bluntly and even square. It is Admiralty practice to specify a gradation of change of fillet radius to ensure that the fillets vanish and I suggest that this is essential if we are to remove these objectionable features. Do the processes of manufacture and machining require any modification for propellers of different materials and does the degree of finish mentioned in the paper apply to all types of material used for propellers ?

Towards the end of the paper the author states that he does not think dynamic balancing is necessary and I make a plea for the suppression of vibration, which is an overriding requirement nowadays. Professor Burrill appears to think that some classes of propellers do call for dynamic balancing and I wonder whether he has verified that a propeller to the tolerances named is in fact dynamically true.

Concerning the thickness of the propellers Professor Burrill shows that the standard, corrected to scale, is much greater than that for a model propeller used in a self-propelled model test. Propellers are made to close standards and if you refer to the Haslar standards mentioned in my paper read in 1949 to the North-East Coast Institution, you will find that they certainly bear comparison with the standards, of the ship propellers mentioned in Professor Burrill's paper. There would be no difficulty in making propellers for self-propelled model tests to those standards, but I do not think that the same degree of thickness tolerance is required for propellers for self-propelled model tests, but rather a refined pitch tolerance.

Another point in the manufacture of model propellers for cavitation tests is to ensure a good smoothness of finish and perhaps Professor Burrill can give information as to the standards of smoothness of the propellers.

Professor G. Aertssen : The list of tolerances given in Table I, to which large marine propellers are consistently finished, is generally smaller than the tolerances given in the proposals to the ISO for Class I, for the majority of merchant navy vessels, manufactured with medium precision. Professor Burrill mentions a method of checking pitches by means of a pendulum pitchometer, whereas the ISO proposal contains three methods, of which none requires a pitchometer. By the first of those methods a certain distance, $P\ Q$, is plotted along the helicoidal line and the difference in height is measured between the spots P and Q, and the pitch angle calculated. I think it is better to calculate an angle from length measurements than to measure it by a pitchometer. The ISO proposal recommends the first method and also recommends the measurement of thicknesses perpendicular to the blade, although blade sections are defined parallel to the shaft centre line.

Mr. K. G. Evans : In future there will be an increasing demand for propellers having complex blade sections and often a continuously changing pitch from root to tip, and I make a plea for " camber " only to be applied to the shape of the mean line of propeller sections, in accordance with normal usage and for the application of the terms " concave " or " convex " to the curvature of the face, to avoid confusion with " camber."

For a hollow-faced propeller it is usual for the designer to specify the distance of points on the face and back from a nominal face pitch line, a pitch line is then drawn parallel to this and tangential to the blade sections, and the first manufacturing operation is to machine the casting to this datum surface. If I understand Professor Burrill correctly, after the propeller is machined to this tangential face pitch, the face is finished by drilling to the required depths and then grinding away. How, then, is the face checked for correctness when this operation is completed and the datum surface removed ? When making model propellers at Haslar it is our practice to machine to the tangential face pitch and then to drill down to the back, which can be checked for thickness and scraped down until correct to within a few thousandths of an inch. Only when the back is finished is the drilling to the face commenced and the datum surface removed. The face can be checked by a thickness survey using the back as the new datum surface. This raises another question relating to the measurement of section thickness. Could the author say how the thickness is measured normal to the face pitch as specified on design drawings ?

Mr. Windsor C. McKenzie : Propellers have an increasing importance for us all because in recent years we have discarded twin screws for single propellers on a number of cargo liners. This is an interesting development, because the propellers had to be designed, before either the naval architect or the designers could decide on the hull and machinery.

Professor Burrill has made little reference to the recess for the rubber sealing ring for the keyway ; but such matters are very important to an operator. The older method of fitting a rubber ring in a recess which is aft of the propeller shaft liner has been discarded, largely because the keyway takes a large section of the space in the propeller recess, and no completely satisfactory method has been found. Proof of that is to be found in that any shipbuilder will show you several methods for retaining the rubber ring and ensuring that it will keep the sea-water out. Therefore, from the owners' standpoint, there is room for definite improvement in that respect.

The outer gland, retained by a series of studs and forcing the rubber ring on to the outer surface of the liner, appears satisfactory, but when an operator puts his ship into a dry dock he wants to turn her round within the period of a few tides, and if she is retained in the dry dock for two or three days more, simply because of a minor defect in that gland, then the modern method of keeping the water out of the internal parts of the propeller box is unsatisfactory.

Dr. G. Hughes : I want to make a suggestion with regard to the basis of the method of design which Professor Burrill has developed ; I refer to the hyperbolic pitch variation and after considering Fig. 5, it occurs to me that there is no serious variation of pitch across the blade at any one radius. In expression (1), it does not appear that the value of that ratio is independent of the angle β ; therefore, there may be an appreciable variation of the pitch across the blade. Actually that is not so, and despite that formidable looking ratio, there is a degree of constancy of the ratio at large angles of β which justifies Professor Burrill's method.

But further development appears to suggest that we do not need that ratio at all. It can be shown that the ratio for the pitch is :

$$\frac{1+e/R}{1+e/r}.$$

I commend that very much simpler ratio instead of the one used.

Professor E. V. Telfer : About a year ago I had to investigate the failure of two bronze propellers which broke at the fillets after eight or nine weeks in service. Investigating the process of manufacture I found that every precaution had been taken to standardise

and control the measurements of the thickness of all blades at a very wide number of radii, but there was no control of measurements in the fillets. In way of the fillets the thickness of the blade, at the most highly stressed section, was 1cm less than the planned thickness. That might be one of the reasons why British propeller designers do not take too kindly to standardisation, because standardisation may be a let-out from responsibility, whereas that responsibility should be fully faced.

A propeller can be made in cast iron which requires no machining of the face and which can improve on bronze propellers by very high percentages and still last, without any erosion at all, for ten to fifteen years. If the practices which go into the making of a cast iron propeller can show such a record of production, I suggest that the bronze propeller manufacturers have a lot to learn from the manufacture of cast iron propellers. For example, in laying off complicated faces the practice is much simpler for cast iron propellers.

In the paper Professor Burrill states that the simplest face form is that of the simple helicoid. That is nearly true, but there is a simpler form, which I have not yet tried. When you look at the flat face of a propeller it is so very nearly flat that I am sure it could be made completely flat and the resulting pitch variation from some approved theoretical design would be very small and would be the simplest of all to machine.

Mr. H. Lackenby : Section 8 of the paper refers to a system of variable pitch striking which gives excellent results in practice and adds that the pitch reduction curve obtained corresponds very closely with that indicated by theoretical considerations. I presume that these theoretical considerations are the efficiency of the individual blade elements in the variable (radial) wake encountered behind a ship.

In a paper presented to the Spring Meeting of the Institution, I think Professor Burrill showed that the form of pitch distribution, i.e. either (*a*) increasing towards the tips ; (*b*) decreasing towards the tips, or (*c*) constant pitch, appeared to make little difference to the performance of the propeller. In view of this I ask whether, from the practical point of view, these rather complicated pitch variations are really worth while.

In that same paper Professor Burrill, in addition to discussing various pitch distributions, dealt also with the effect of a variable wake ; in other words, he endeavoured to ascertain the effect of the presence of the ship on the performance of the propeller, but I think he did not consider the effect of the propeller on the ship, i.e. the effect of pitch distribution on the overall propulsive efficiency. The relevant factor here is the thrust deduction and I think this is likely to be improved slightly by reduced pitch towards the boss.

With regard to surface finish it is now widely accepted that the surface roughness of a ship's hull is very important from the point of view of resistance and there is little doubt that it will also have an important influence on propeller performance. One of the few references to surface finish in the present paper is the statement that, after trimming, the final back shape is made fair and smooth all over ; and the final sentence states that the propeller is polished all over. Are any measurements made of this ? What is the polishing process ? Are there any limits set on this for acceptance purposes, and are there different standards of finish for different classes of work ?

Professor Burrill, in reply : With regard to the measurement of thicknesses parallel to the shaft axis, the answer is simple, the back is marked off as well as the face and it is easy to put through a vertical line and therefore to put the points on the back. The difference between the standards proposed by the International Standards Organisation committee and those to which we are working is that we have one standard and do not recognise standards 2 and 3 ; all standard propellers will be made to these tolerances. We have had a long experience and I am afraid that we are inclined to prefer our own high standards.

In reply to Mr. Shepheard, I say that in the main I am referring to commercial standards, which are most exacting. There is no doubt that the ability to machine the whole of the face does reduce the work in the foundry and also the time of machining.

The question of root fillets is one which obviously requires care and the only way to ensure that the fillets are correctly shaped is to have templates which fit exactly in the fillets around the propeller. But when the fillets are important from the erosion and precision points of view I suggest that designers should study the shape of the blade as it comes down to the root.

I cannot accept Professor Telfer's remarks about the fillets being the cause of the breakages to which he referred. It is usually assumed that the concentration of stress occurs at the top of the fillet and that is definitely measured.

The second paper read on Wednesday morning was :—

THE HYDROMECHANICS RESEARCH PROGRAMME OF THE BUREAU OF SHIPS, U.S. NAVY.

By F. H. Todd, B.Sc., Ph.D.

Synopsis

This paper gives some account of the organisation of naval research in the United States, and in particular describes the scope and methods of administration of the Bureau of Ships Programme of Fundamental Hydromechanics Research. This programme is planned in close association with other agencies engaged in this field, such as the Office of Naval Research, the Society of Naval Architects and Marine Engineers, the American Towing Tank Conference and various universities and laboratories.

The research work under the programme is carried out partly in the Navy's own laboratories, partly in the universities, the responsibility for the planning and administration of all the various projects being vested in the Commanding Officer and Director of the David Taylor Model Basin. The paper describes these projects and some of the results obtained in different fields.

An account is also given of recent developments in facilities and instrumentation.

Discussion

Mr. V. G. Shepheard : The author has presented a valuable paper which is more than a research programme. Unfortunately, we in Great Britain have not been so generously provided with facilities as have been our friends in America, so we have to concentrate on research items which will pay the best dividends in those warships likely to be built in the future.

The research programme has been organised under eight main headings. This is a neat and concise division, but it requires little imagination to visualise that each item includes a wide range of subjects. In the programme the item which holds the greatest promise of improvement in the performance of all classes of ships is research in ship motion and seaworthiness, with which I include a study of ship resistance and propulsion among waves. This is a subject about which little is known, and I note that the Bureau of Ships is instituting a comprehensive study of the problem. The emphasis in the past has been on designing for the best ship performance in smooth water, but the naval architect and the shipowner is more interested in the best performance under average seagoing conditions which might well involve changes in form. In warships the problem goes further, as there is an increasing requirement for improved performance and reduced motion in rough weather.

The plan mentioned by the author to encourage the interests of the universities is commended, and in Great Britain considerable benefit has been derived from this source, particularly in the theoretical fields. Overlapping of research effort must be avoided in the interests of timely results, and ship tank superintendents have made some advance in co-operative and complementary research in the past and it is hoped their efforts will be well maintained.

Professor Dr. Ir. W. P. A. van Lammeren : Comparison of this paper with mine shows that the research described by Dr. Todd is of much broader scope and is supported by means which are not at all comparable with those that I mentioned. One is impressed by the mighty organisation and by the quantity of subjects on which work is in progress in the U.S.A., even if only the field of hydromechanics research is considered.

Close consideration of the paper shows that the hydromechanics research programme covers a great number of more fundamental subjects, each of which brings new problems, and is a happy circumstance that the means at the disposal of the Taylor Model Basin enable this establishment to provide the complicated instruments and facilities needed for the realisation of the programme.

Owing to the limited funds available in the Netherlands, we must restrict ourselves to practical subjects to give a more perfect service to shipbuilders and shipowners.

Apart from the review of the organisation and of the research work now being carried out, the paper gives much experimental data. I do not agree with the author's remark that the many non-systematic model tests that have been carried out in the past cannot really help in the design of optimum ship forms. A carefully built up system of statistics for a number of ship types will enable the designer to find the best solution for any specific design condition. Further systematic series on parent lines may render more easy the judging of performance, and I favour the author's suggestion to use the results of the new methodical series 60 as a basis for the correlation of research work throughout the world.

Professor E. V. Telfer : Early in the paper Dr. Todd refers to the fact that two-thirds of the United States scientists and engineers are engaged on (and nearly 1500 million dollars a year are spent on) military and defence research. I refuse to believe that the prosperity of the United States can be maintained by only one-third of their scientists and engineers. That shows either that the better scientists and engineers are still out of the research field or that scientists and engineers do not matter at all so far as the economy of a country is considered.

Dr. Todd considers it to be to the credit of the American Towing Tank Conference that in 1947 they adopted the Schoenherr friction line and also the roughness correction, but I do not endorse that statement for one moment. I think it is to their shame that they dropped the Froude immediately and went to the Schoenherr.

Dr. Todd refers to series 57 and to the fact that some forty organisations helped to

select the best pattern as a basis, and also to the fact that series 57 was probably one of the worst forms in the world's ships. This shows how little we know about the choice of optimum forms, and I hope that in series 60 Dr. Todd will have found not only a better form, but the reason why series 57 was such a disappointment. If he can give us that reason, I think that that one point alone will fully justify the writing of the paper.

Professor G. Aertssen: With regard to the tank tests and full-scale ship trials, there is correlation which is hardly influenced by the laminar flow existing over the entrance of the model. Dr. Todd has mentioned different turbulence-stimulating devices, and I understand that studs were used originally for this purpose by the Ship Division of the N.P.L. Some months ago, full-scale trials were undertaken on a "Victory" ship, and models were run by the N.P.L. and the Taylor Model Basin in order to correlate the tank test and the measured mile trial. At Teddington, the model was fitted with a standard trip wire 0·036in in diameter, girthing the model at station 9½, whereas at Washington turbulence was stimulated by means of studs. I mention these facts in case both tanks may have an interest in making a comparison.

I admire the work done on semi-full-scale on the "D. C. Endert, Jr.," by Professor van Lammeren, but I feel that until his project of towing the "Victory" ship is carried out successfully, velocity measurements in the boundary layer of ships will contribute in large measure to a better knowledge of skin friction. Although such work is difficult to do on full-scale trials, I feel that it should be done whenever possible.

Dr. R. W. L. Gawn: Dr. Todd has unfolded to us a very wide plan dealing with the steps being taken to improve ships. He commends the work of those with whom he was associated on the various committees, but I hope he will not forget those who carry out these researches. Some of the work is of a long-term character, and for the best results the research workers must be given a real interest in their subjects.

In connection with roughness of hull, the "Lucy Ashton" paper, presented earlier this year, included some useful results of the measurement of the degree of roughness of the hull surface, and they were allied with actual resistance measurements of the ship. I hope to give with my remarks in the discussion a diagram showing these measurements, together with the measurements of the surface of a propeller, which is representative of the 20in series, on which I read a paper last year. In that paper is was shown by deduction from the thrust and torque measurements that the resistance of the surface fell on the turbulent skin friction line. You may deduce from that, that if you could produce a ship's surface of similar smoothness, the resistance of a short ship would be reduced by 12 per cent, and of a longer ship by amounts up to 20 per cent.

I notice that the resistance of a zinc chromate surface was near the turbulence line, and I suggest that the results for the zinc chromate surface be included on the diagram so that we may see how it compares with the propeller. I also suggest that if this surface is established as ideal for turbulent flow, this question of roughness leaves the realm of the hydrodynamicist and passes into that of the shipbuilder.

I should be glad if Dr. Todd would elaborate on the pneumatic wave make-up. It is clear that on a small installation the waves are beautifully regular, but can we have the assurance that on a large equipment he will succeed in reducing the mechanical inertia to such an extent that the waves created will not suffer from lack of uniformity.

Professor A. F. Lindblad: In the subsection headed "Methodical Research into Hull Form," it is stated that: "Although the parent lines were selected from a number of models having acceptable resistance characteristics, it was found that in fairing the cross curves and contours some of this good performance had been lost." You cannot get one group of a few single models which will suit all the different block coefficients and get good overall research. You have to select them and put them into smaller groups and work from those groups instead. I hope they will succeed a little better with series 60, although I am doubtful about that.

Much is said nowadays about bulb forms, and I ask why series 57 was selected. Is there some kind of military advantage in fitting such bulbs to ships? I have done some research on those lines and have compared the bulb forms with other lines, and there are many instances in which advantage is gained from small bulbs, and with large bulbs you can also obtain good results, but in my opinion it is not good to have just a full form.

Dr. G. Hughes: It is stated that the stud method of stimulating turbulence was developed by the Ship Division of the National Physical Laboratory, and do Dr. Todd's remarks infer that the Taylor Model Basin is now using studs as the standard method of stimulation on model hulls? Although at Teddington we use the studs we still employ the trip wire as the standard method of stimulation in all commercial work, not because we think the trip wire is better than the studs, but because the work in the model range with which we are dealing shows that there is little difference. However, studs are definitely superior to the trip wire at the lower speeds.

Dr. Todd refers to work which is in progress at the model basin using studs at different distances from the forward edge of a flat plate in order to study the mechanics of turbulence stimulation. The transition zones are made visible by spraying the plate with a chemical indicator, and I ask just how effective are those indicators and the hot wire anemometer in telling the degree of resistance on the forms? It is stated that the experimenters are satisfied that the methods used for the flow indications are satisfactory qualitatively, but not quantitatively, and it seems that while they give a general indication of the type of flow, if they are used to decide what is the real degree of turbulence obtained, these flow observations must be linked directly with the corresponding resistance observations in the same tests.

I disagree with the reference to the flow, "mapping out the areas on a ship model or plank over which the flow is laminar, transitional or turbulent." I do not think the author means that the flow can be transitional, for, as I understand it, the flow is either laminar or turbulent. Does he mean that in the transitional areas the flow is at one instant laminar and at another turbulent? We have done a good deal of work recently on turbulence stimulation and resistance measurements, and have been surprised by the remarkable stability of any one result, whether there be any laminar flow in the actual case or whether it be all turbulent.

Whilst the investigations described in the paper are well worth while and will lead eventually to much greater knowledge concerning flow on ships' hulls, at Teddington we are not pursuing this particular approach, but concentrating on the overall picture as given by the resistance results, basing our conclusions on the consistency or otherwise of those results. I commend that particular method to Dr. Todd, because it will give the more immediate answer to our problems.

Mr. T. W. Bunyan: Most engineers will be interested in the explosion of the mystery which has for many years surrounded the aperture of a single-screw vessel. This is particularly important, because we know that a tight aperture clearance behind the propeller can have serious consequences. In tanker geared turbine machinery there may be one, two or three-noded induced torsional vibrations distributed throughout the running speed, and Lloyd's Register of Shipping, in conjunction with the tank at Teddington, has undertaken to sort out some of these propeller-excited shafting vibrations, and I hope that Dr. Todd will also include this problem in his programme.

The reading of papers was resumed in the afternoon of Wednesday, September 16th, with Sir Stanley V. Goodall in the chair, when the final paper presented was:

INVESTIGATIONS OF SHIPS' HULL AND MACHINERY DEFECTS

By T. W. Bunyan, B.Sc.

Synopsis

Machinery defects fall into two categories. The first includes failures as a result of neglect, lack of maintenance or accident, and a technical investigation is hardly necessary to ascertain the cause. The other category of failure may result from inadequate design due to lack of knowledge or experience or due to unforeseen circumstances in service. Investigation into the causes of the failure may require a critical study involving advanced measuring and recording techniques and practical experience. Recent years have seen advances in the art of measurement, the most notable being the application of electronics and the electrical resistance strain gauge, which gives direct quantitative measurement of high accuracy.

The Research Department of Lloyd's Register of Shipping includes, as part of its equipment, a variety of the latest instrumentation and techniques for recording and analysing such quantities as temperature, pressure, mechanical strain, noise and vibration, and it has developed special techniques of its own to deal with specific problems.

An attempt has been made to present a few examples of techniques which may or may not be new to many of the readers, and illustrations have been given from actual jobs done and the results that have been achieved.

Discussion

Mr. R. J. Anderson: The form of applied science professed by the naval architect seems to have reached the state of affairs common in other branches of engineering, for while keeping his interests focused on the main issues he must be aware of recent developments all round the fringes of his subject.

The engineer has organisations ready to provide useful information and in England there are the Government Research Laboratory under the ægis of the D.S.I.R., the trade group research organisations such as the B.S.R.A. (representing the shipbuilders) or Lloyd's Register (representing the shipowners), and the large industrial firms.

In the field of non-destructive testing the author has given us some useful information and it is reassuring to know that the data here presented are available for future reference.

Coming directly under the title of the paper is the variety of instruments based on eddy current loss principles, and I feel that these should have been mentioned. One application is for sorting. For example, the differentiation between turbine blades of similar dimensions but different alloy steels, by means of a device which consists of the

determination of the voltages generated by friction between a standard metal and the unknowns—each material having its own characteristic voltage. By far the most useful is the inspection, or non-destructive testing, of non-ferrous tubes by an instrument, of American origin, which has been developed in a number of forms, but it is generally known as the Probolog. In practice a probe, containing two arms of an inductance bridge, is drawn through a tube at a fixed rate of either 12ft or 24ft per minute, and at the same time a record is made, on a strip chart, depicting the local changes of resistance along the tube. These changes are caused by pits, holes, dezincification, &c., in terms of which they may be interpreted, although results may be influenced to some extent by such factors as hardness and dimensional changes. Hence the interpretation of results is a matter of experience and is not to be undertaken lightly.

Nevertheless, much more rapid and satisfactory testing is now possible than by the use of an Intrascope or any other means of *in situ* inspection ; and the withdrawal at random of numbers of suspect tubes for sectioning and internal examination is almost a thing of the past.

Dr. T. W. F. Brown : In connection with sound measurement and analysis, Mr. Bunyan does not make it clear that there are two specific types of investigation. First there is axi-analysis, which is the dividing up of the total source of sound into proportions at each octave. But if you wish to try to cure anything you must have creep analysis ; in other words, your total source of sound is worked through a sound analyser, which gives the amplitude and frequency generated by each of the excitations. For example, for double reduction gearing you may not be able to find even the particular generator of sound because it may be in the original kinematics of the generating machine. This is what we know as the "phantom wheel." Measurements can be made with great accuracy and we expect to be correct to one in a million, and are sure that we can achieve an accuracy of one in two million.

Mr. Bunyan refers to a noise level of 93 db in presumably a reduction gear, that is a very good figure, for the average in good practice is about 103 ; and as the sound level scale is a logarithmic one, the energy being dissipated in the sound is considerably greater.

The author says that an improvement will be obtained with hardened and ground gearing and that is so if it is operated at the same loading as a shock gear ; if a shock gear has a Brinell hardness between 190 and 220, and a hardened and ground gear has a Brinell hardness of 450, then the latter will be the quieter. But who is going to make a hardened and ground gear, with all the metallurgical problems of distortion, involving hobbing, further hardening and subsequent grinding, to operate at the same load? If you use the hardened and ground gear to its full capabilities it is definitely the noisier gear.

Electric strain gauges suffer severely from drift and if you pursue an experiment over a period of time it is essential to be sure that you are measuring strain and not drift. The strain gauge is at its best in measuring dynamic stresses, going through a zero stress ; then you know whether or not drift is occurring. Mr. Bunyan mentions the word "static," and this means trouble unless your static is tied into a very short time interval, for if the static occupies a period of weeks then extreme care should be taken to ensure that drift does not occur.

Mr. Bunyan advocates the use of the Geiger instrument for measuring low-frequency vibrations and that is probably quite wise for ordinary practice. A lot of people use the Geiger for measuring torsional oscillations, but it is made for measuring low frequency oscillations.

With regard to torsional oscillations on geared turbine systems, especially with super tankers, increased dead weight and speed mean powers of 28,000 h.p. through one shaft, and in certain instances it is clear that the one and only torsional critical is below the working speed range ; but in others it may be within the speed range. In the two-nodic torsional vibration, even where it occurs close to the running speed, because of the automatic damping in the turbine and in the gearing, you may be quite close in one of the gears to a two-nodic vibration without having a very serious increase in torsional stress.

On the axial vibration of the propellers and shafting, if you make the ordinary calculation you have a large mass in the propeller, a spring system up to the thrust block and the calculation is simple to make. But you have to use a factor of approximately 0·6 to reconcile the axial vibration measured on board ship with the calculated value since a further spring system has been interposed between the thrust block and the ship.

Professor E. V. Telfer : The problem of adequate clearance in propeller apertures is a difficult one. On the one hand, you want to give adequate clearance from both the body post and the rudder post, but in doing so (so far as the body post is concerned) you tend to steepen the angle of entrance of flow and a breakdown occurs in front of the propeller ; so that by giving more clearance you have caused greater trouble with the propeller than you would have had by coming nearer to the propeller itself with a smaller angle of entrance into it. For that reason I would have liked to know whether that particular point was explored in the N.P.L. experiments, because the Washington experiments showed that the probable explanation for the experience with series 57 was bad aperture resistance on an otherwise reasonably good hull.

Another aspect of aperture resistance is not concerned with fore and aft clearances. I have fitted many ships with rudder post fins, and in only a few did vibration result. However, the non-streamlined design of fin did produce vibration. Most of the trouble with propeller vibration is due to presuming that a streamlined rudder, possibly 15in to 18in wide, is streamlining so far as the propeller is concerned, and that too much clearance will put too steep an angle of flow into the propeller. The solution does not lie along those lines, but in slimming the rudder and hence streamlining, and reducing the angle of flow into and the angle of exit from the propeller.

The author invites criticism in regard to propellers having an odd number of blades. I have adopted the five-bladed propeller as the solution of vibration and flow breakdown problems, and I do not agree that the adoption of a five-bladed propeller is a drastic process.

Tankers are presenting many problems, and definite changes in outlook must be taken before we can guarantee that 22,000 h.p. from a single propeller and a streamlined rudder represent the best we can obtain with a single-screw job.

Mr. Bunyan, in reply : I agree with Mr. Anderson that instruments based on eddy current loss principles, for sorting, and so on, can be very useful. My value of 93 db was measured under full power conditions, but the equipment was not very large, about 4000 s.h.p., and in connection with hardened and ground gears working at very high K factors, I agree that unless you have these high K factors it is not an economic proposition. We would not consider the use of strain gauges where we were likely to have a static condition lasting a week. We have made complex stress analyses on fractionating columns for the oil industry, complex sections of wind tunnels, &c., involving the use of a large number of gauges, and the greatest care is taken to minimise drift. The "Geiger" is a mechanical apparatus and gives a direct record, and while I do not think it is perfect, it stands hard usage, it is easily calibrated, easily stripped down and can be adapted to do many other jobs.

The problem of aperture resistance has given us a lot of thought, and I draw attention to Fig. 7 in the paper, where you see the improvement that was attained by attention to the propeller trailing edge and the nose of the finned stern post. Incidentally, in these ships, we had a streamlined stern post and a thin rudder.

As to five-bladed propellers, I concluded that, with the eccentric transverse forces and the reactions that might occur with a propeller having an odd number of blades, the transverse bending component for the tailshaft might be more than with a propeller having an even number of blades.

Cargo Handling Symposium

THE International Cargo Handling Co-ordination Association held a Unit Load and Palletisation Symposium on Thursday of last week on board the "Wellington," the headquarters ship of the Honourable Company of Master Mariners. Over 100 members of the Association attended, together with a number of foreign delegates, and four papers were read. The first paper, entitled "Unit Loads and Palletisation," by Monsieur A. Vincenti, described the progress of palletisation in France in both sea-borne and internal transport, and touched upon some of the problems raised. The size of pallets in use was mentioned, the various applications discussed and advantages in particular trades enumerated, particular problems referred to being the strengthening of quays and warehouse floors to withstand the use of fork lift trucks, and the handling of unit load on board ship. Mr. John H. Bustard read a paper on "Road Transport Afloat," which referred particularly to the employment of converted "Landing Ships Tank" for ferry services, and instanced those operating between Tilbury and Hamburg and between Preston and Northern Ireland. The drive on and off of this design of ship and the growth of the traffic to Northern Ireland were described, together with the advantages of this form of service, while a film illustrated the actual operations. The third paper, given by Mr. Douglas R. Woodley, was entitled "The Case for Palletisation," and set forth the advantages of the system. Fork lift trucks were grouped into three categories, and the paper which discussed such items, as factors of choice, recent developments and cost comparisons, included illustrations showing various forms of pallets and handling problems. "Ship Types and Through Transport" was the title of the last paper, and was presented by Commander A. C. Hardy. This paper generally considered the past, present and future designs which co-ordinate road, rail and sea transport. Details of the American Seatrains were given, together with those of the Trailerships, and reference was made to the "Carport" pusher-tow design. Among the transport proposals mentioned in the paper were the Swedish North Sea Ferry Scheme and the "Bylo" method of handling water-borne cargo.

Uskmouth Power Station

Uskmouth power station, which is built on a site flanked by the River Usk and the Severn estuary, was formally opened by the Mayor of Newport on October 7th. Two of the six 60MW hydrogen-cooled turbo-alternator sets are now in commission. Steam is generated at 950 lb per square inch and 925 deg Fah. by pulverised fuel-fired boilers, of which there will ultimately be twelve, each with a capacity of 360,000 lb per hour. The site provides easy access to coal supplies and circulating water.

THE commissioning of the first two 60MW generating sets in Uskmouth power station marks an important stage in the task of making South Wales self-sufficient in electrical power. Shortage of power in South Wales is mainly a result of post-war industrial development, whereas, before 1939 this area was, on the whole, an exporter of electricity. By 1948, however, electricity was being imported at peak periods and by the middle of last year these imports represented about one-third of the peak load.

Plans for Uskmouth power station were first discussed by Newport Corporation soon after the end of the war and the approval of the Central Electricity Board was obtained in September, 1946. In its initial stages the project was the responsibility of Mr. T. H. Wood, borough electrical engineer of the Newport Corporation, who was appointed consulting engineer for the station. After vesting date the scheme passed under the control of the South Wales Division of the British Electricity Authority. On being appointed chief generation engineer (construction) of the South Wales Division, Mr. T. H. Wood continued his association with the building of Uskmouth power station under Mr. H. V. Pugh, who was then controller of the division.

Civil Engineering Work

The power station is built on a 600-acre site where the River Usk joins the Severn estuary. The site was formerly grazing land, lying from 4ft to 6ft below maximum high tide level and, though protected by earth banks, it was subject to occasional flooding.

Work on the excavation of the basement of the main power station building was started in October, 1948. Sheet steel piles and a hard-core bank were used to seal off a gully known as Thieves Pill running into the north-west corner of the site. Here the strata formation consists of a 12ft deposit of peaty clay, hardened by drying, overlaying a 20ft thickness of soft clay. Next there is a bed of sand mingled with silt and clay, from 5ft to 20ft thick, above a layer of stiff clay and small stones. Below this there is a hard base of sand, gravel and boulders at a mean depth of 70ft below ground level.

Some 6800 piles about 70ft long had to be driven to provide foundations for the building. Serious difficulties were met, particularly in the closely-spaced groups of piles under the chimneys. At the west end of the site it was necessary to drive tubes and to core out to depths below the sand belts, a 70ft pile being pitched in the tube and driven the last few feet into the marl.

Work was started in March, 1950, on the reinforced-concrete circulating water ducting. Much of this ducting is circular, of 8ft diameter, but below the main building the cross section is square, measuring 8ft by 8ft. The total length of circulating water pipework is about 1½ miles.

The ducts were laid on precast piles. Where possible a part-open cut was dug and a sheet piled trench was taken down to the required level before starting pile-driving. Trench strutting built up of boxed pile sections was formed ahead of the pile frame as it advanced. By stripping the frame of its boiler and winch and by mounting it on a light base it could be hoisted bodily by 7-ton derricks travelling beside the trench at ground level.

To ensure supplies of circulating water at low tide levels a caisson was sunk on the foreshore at Uskmouth. This caisson*, which forms the substructure of the pump house, measures 164ft by 110ft by 80ft, weighs 40,000 tons and is believed to be the largest ever sunk under compressed air.

The all-welded steel structure forming the caisson shoe and working chambers was divided into three equal compartments by building two internal bulkheads, housing spine trusses carrying roof trusses over the working chambers. Because of the weakness of the foreshore the steel shoe of the caisson had to be assembled on made-up ground away from the river bank. The 580-ton shoe was built up on ball carriages beyond the river bank and was rolled out on two tracks along the line of the bulkheads to a position just above its final site. There it was lowered by hydraulic jacks to a level hard-core bed prepared on the foreshore. Six airlocks were provided and the buckets for removing the

* The Engineer, July 20, 1951, page 93.

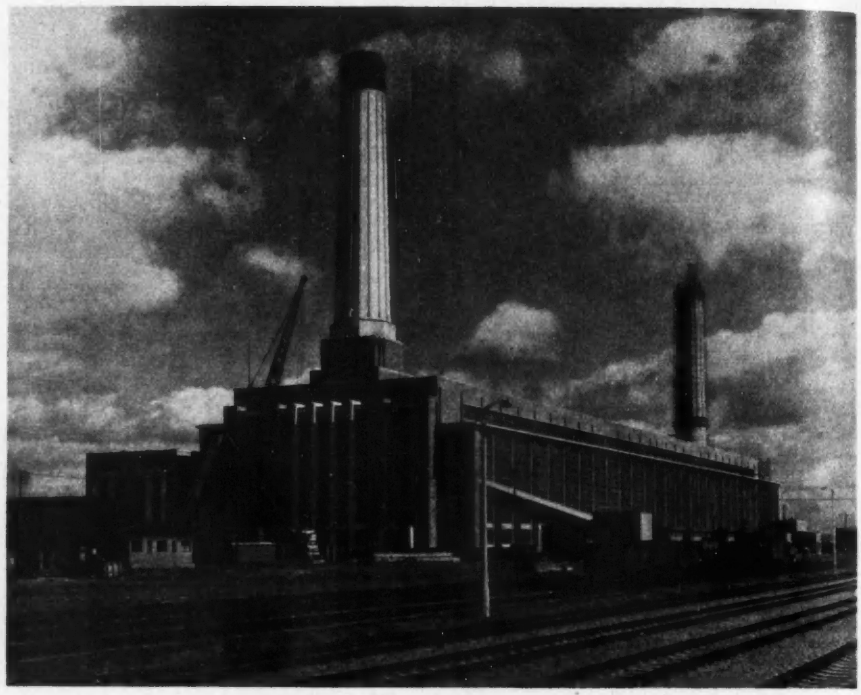


Fig. 3—Uskmouth Power Station from the South

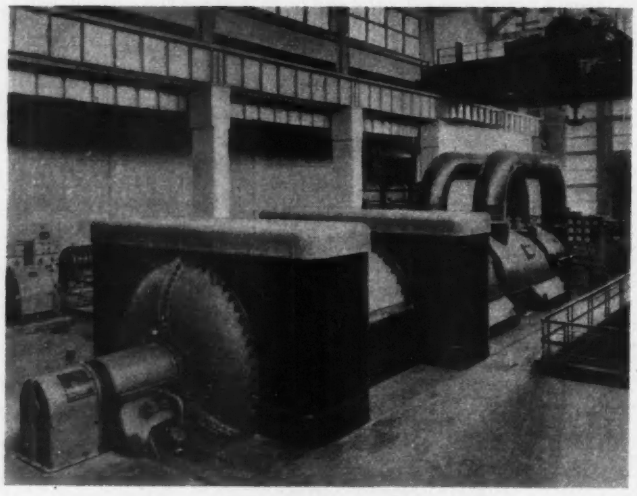


Fig. 1—No. 1 Turbo-Alternator Set

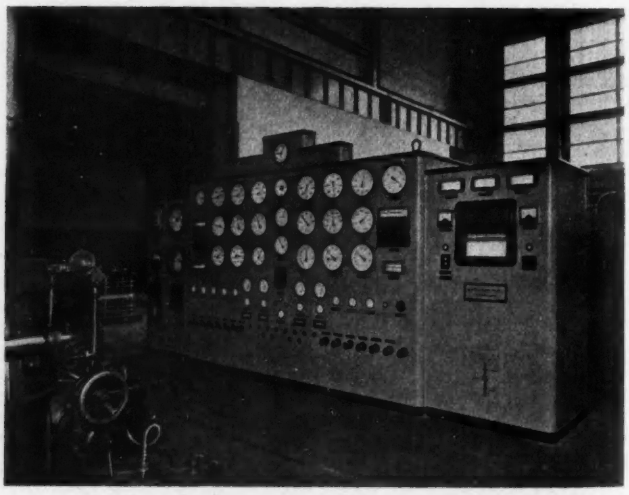


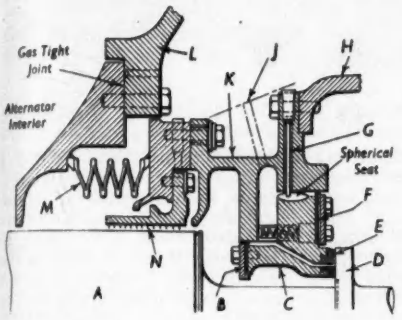
Fig. 2—Turbine Control Board and Supervisory Panel

excavated material from the working chamber were handled by six 2-ton electric derrick cranes mounted on the caisson structure.

The power station buildings (Fig. 3) are steel framed and brick clad, with roofs consisting of precast concrete slabs overlaid with cement screed, granulated cork and asphalt. There are two 300ft reinforced concrete chimneys—one at each end of the boiler house. The main building is 896ft long by 270ft wide. The operating floor level is +34 o.d., the basement level + 6 o.d., and the general ground level 28 o.d.

Between the N.W. face of the main building and river bank is a separate building housing the 132kV air blast switchgear and the control room. This building was specially designed to withstand the shock associated with the operation of air blast switchgear.

The civil engineering consultants were Messrs.



A. Rotor shaft.
B. Cup seal.
C. Gas seal ring.
D. Shoulder for oil seal.
E. Oil seal face.
F. Cup seal.
G. Seal ring locating pin.
H. Bearing pedestal.
J. Seal oil inlet.
K. Seal housing.
L. Alternator end cover.
M. Expansion bellows.
N. Oil wiper.

Fig. 4—Arrangement of the Shaft Seal

Mouchel and Partners, Ltd., for the station, and Sir William Halcrow and Partners, for the river intake works.

Coal Handling and Boiler Plant

Coal for Uskmouth power station is rail-borne, and is handled by a plant in two sections, each of which can deliver 300 tons of coal per hour to any of the twelve boiler house bunkers. From the railway trucks, coal is discharged into two double-sided waggon tipplers and is carried on two 36in belt conveyors to a central position, whence it is distributed either to the stockpile, by bulldozers or, through a crushing and screening plant, to the bunkers by belt conveyors. The boiler house bunkers are of reinforced concrete, and each bunker has a capacity of 700 tons. The coal store covers 11 acres and has a capacity of 108,000 tons, with a storage depth of 10ft.

Coal is fed under gravity from the bunkers into the pulverising mills, of which there are three per boiler. The twelve down-draught burners along the front of the furnace chamber are fired initially from an electrically ignited oil-fired lighting up system. Each Bailey Hopper furnace has a heating surface of 4625 square feet and a volume of 26,500 cubic feet.

Duplicate boiler draught plant is provided. To reclaim some of the heat radiated from the boilers, the air for the forced draught fans is taken from the top of the boiler house. Each forced draught fan supplies air to a rotary heater. After traversing the boiler, superheater and economiser surfaces, the combustion gases pass through the gas side of the air heaters. Dust and grit are removed by mechanical Howden "Centicell" collectors and Sturtevant electrostatic precipitators before the gases are discharged to the main flue and chimneys.

Under each boiler there is a water-filled ash-hopper in which the hot ash is quenched. Ash is discharged periodically from the hoppers into a sluiceway whereby it is flushed into a central ash pit by the "Hydrojet" system. A similar system discharges the dust and grit from the precipitators to the ash pit. From this pit the ash is passed through a crushing plant and the mixture of ash and water is then pumped to a disposal ground, where it is spread to dry and, eventually, to be covered with soil.

The boilers are high-head single drum Babcock and Wilcox units, with multiloop draining superheaters, the primary heating surface being 10,800 square feet and the secondary 3960 square feet. There are two surface attemperators per boiler, each with a heating surface of 241 square feet. The multiloop economiser has 21,100 square feet of heating surface. Each boiler has two Howden Ljungstrom air heaters, each with an effective surface of 25,950 square feet.

The steam from each pair of boilers is delivered at 950 lb per square inch and 925 deg. Fah. to a steam receiver, with two feeds to the associated turbine. A branch pipe leads to an auxiliary steam range supplying the central evaporating plant, de-aerators, steam feed pumps, ejectors and space-heating system. To make the best use of the available boiler capacity, the six steam receivers are connected in pairs.

Each boiler is provided with Kent automatic control which operates through the medium of compressed air and controls the fuel supply, steam pressure, combustion air and furnace pressure, in accordance with the load.

Steam Turbines

Each G.E.C. turbine is designed for a M.C.E.R of 60MW at 3000 r.p.m. Normal steam conditions at inlet are 900 lb per square inch, 900 deg. Fah., and the normal vacuum at 60MW load with circulating water at 56 deg. Fah, is 28·9in. (30in bar). Feed-water heating is effected in five stages to a final temperature of 385 deg. Fah. at 60MW.

The turbine has two cylinders with twenty stages in the high pressure casing and six stages on each side of the double-flow low pressure casing. The steam inlet to the h.p. casing is adjacent to one of the l.p. exhaust casings, so that the steam flows towards the front pedestal, thence through two overhead pipes to the centre of the l.p. casing, where the flow divides towards the two exhausts—an arrangement which, as described in the next paragraph, simplifies thermal expansion problems.

The turbine and alternator rotors are rigidly coupled together and only one thrust bearing is provided. It is located next to the journal bearing at the steam inlet end of the h.p. rotor almost in the vertical plane of the transverse keys which secure the l.p. exhaust casing to the foundation girders at this point. Thus the thrust bearing is virtually fixed and both the h.p. and l.p. casings and their respective rotors can expand freely and independently in opposite longitudinal directions, thus maintaining approximately constant blade clearances. It will be noted that at the exhaust end the h.p. rotor has no resistance to overcome in its expansion. The l.p. turbine rotor and the alternator rotor are joined by a solid coupling provided with axial clearances which together with expansion pieces in the hydrogen seals accommodate the expansion of the l.p. and alternator rotors.

The moving blades are milled out of solid bars, molybdenum stainless iron being used in the high temperature zones and rustless steel elsewhere. The blading is designed for impulse conditions at the inner diameter of the blading annulus, the degree of reaction increasing towards the outer diameter. The shaft glands, balance piston and interstage packings are of the steel vernier labyrinth design. Oil for the bearings, governor relay and the hydrogen seals is supplied by the main oil pump, an automatic auxiliary oil pump being provided for emergency service. A seal oil pump maintains oil supply to the hydrogen seal when the set is shut down.

Throttle governing is used from no load to full load, the four governing throttle valves being arranged to operate in parallel to give the M.C.E.R. at full load. The throttle valves are built into the h.p. casing around which they are arranged symmetrically to ensure uniform distribution of steam which is supplied through loop pipes connected to the two emergency stop valves mounted on foundation girders. The emergency valves are under the same control as the throttle valves, both being relay-operated from the main governor. The emergency valves move in unison with, but at a larger volume setting than, the throttle valves, and therefore when running below 90 per cent full load, the former are always being moved, thus reducing the possibility of the valves sticking in the guides. Furthermore, at no-load governing is made easier for synchronising.

Superimposed on the speed governor system are two devices for enforcing a gradual load reduction in the event of either a falling vacuum or a falling boiler pressure. In addition, the trip gear ensures immediate shut-down in the event of emergencies such as over speed, oil pressure failure, vacuum failure, thrust failure and certain faults on the generation side. Whenever the turbine is tripped from any of these causes an oil pressure operated switch and relay system disconnects the generator from the busbars.

The condensing plant for each turbine consists of Hick Hargreaves twin condensers with a total surface of 47,000 square feet designed for 28·9in vacuum with 40,000 g.p.m. of water at 56 deg. Fah.

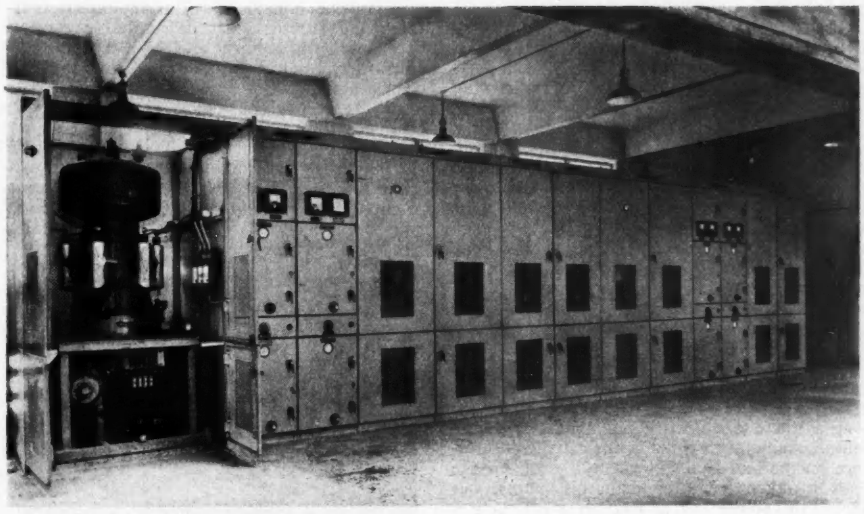
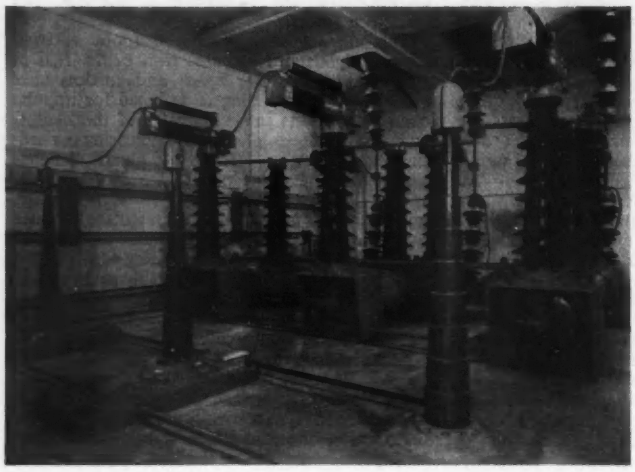


Fig. 5—Rectifier Equipment for Nos. 1 and 2 Boiler Fan Motors

Alternators

The G.E.C. hydrogen-cooled alternators, one of which is seen in Fig. 1, generate at 11·8kV, 50 c/s. For these machines the pressure within the stator is of the order of ½ lb per square inch above atmosphere. The hydrogen gas cooling system is self-contained, the hydrogen circulation being confined within the alternator, thereby eliminating any external ducting. Fans mounted at each end of the rotor shaft force the hydrogen through the stator core, winding and rotor.



Figs. 6 and 7—132kV Air Blast Circuit Breakers and Busbars

The warm hydrogen then passes through the four coolers which are built into housings located at the ends of the stator. Town water is used in the coolers and is passed through heat exchangers where it is cooled by river water before being recirculated in a closed circuit.

The pressure and purity of the hydrogen within the machine are automatically controlled and measured and a comprehensive system of alarms gives warning of low purity, high or low pressure and the presence of water in the alternator casing. Thermocouples are provided to give temperatures of the gas seal rings, of the "cold" gas, of the town water inlet to the coolers, of the river water inlet to the heat exchangers, as well as of the copper and iron at various points in the stator.

The gas coolers are mounted vertically in their housings in such a way that no cooling water pipes are visible on the turbine house floor. They are so arranged that any one can be isolated and cleaned with the alternator operating on a reduced load, special flushing valves being provided for the purpose.

Since the stator frame and cooler housings are built as separate units, they can be despatched separately so that the weight of individual parts which have to be handled on site is kept within reasonable limits.

To maintain the purity of hydrogen within the machine and to economise in the consumption of hydrogen a gas seal (Fig. 4) is provided between the rotating shaft and the stationary stator casing. A collar forming part of the shaft is provided on the hydrogen side of each of the main bearings. A seal ring with a white metal face is maintained in contact with the surface of the collar by means of a spring and oil pressure, the oil being fed to a small annular groove in the white metal face from which it flows radially outwards and inwards.

The inner periphery of the seal ring is not grooved but presents a continuous surface to the collar and forms a perfectly gas-tight seal so long as there is a flow of oil. The seal ring is self-aligning and thus maintains a uniform pressure on the seal face. Normally the oil for the seals is taken from the main oil supply, but should this source fail, an emergency oil pump is started up through the action of an oil pressure switch. An alarm operates if the oil pressure falls below a safe minimum. After passing through the seals the greater part of the oil flows into the main bearing lubrication system, but any oil which may leak to the hydrogen side of the seals drains through a pipe of large bore into a hydrogen detraining tank where the entrained gas bubbles can escape while the oil is in a comparatively quiescent state before it is returned to the main oil tank.

It is stated that the hydrogen leakage in service has proved to be of the order of 13 cubic feet of gas in twenty-four hours.

Each alternator is excited by a separately driven 196kW exciter set which embodies a flywheel whereby full output is maintained for a short predetermined time in the event of a reduction in the voltage or a temporary interruption of the a.c. supply to the squirrel-cage driving motor.

Supervisory Equipment

Supervisory equipment is fitted to the steam turbine and the alternator to provide a continuous record of any shaft distortion or eccentricity, and of speed and alternator rotor temperature. The indicating and recording instruments are mounted on a panel designed to line up with and form part of the turbine control board (Fig. 2).

Shaft distortion and eccentricity are measured electro-magnetically. Incorporated in the governor bearing pedestal are several magnetic detector coils mounted on a gunmetal ring. Rotating within the detector coil assembly is a disc which is machined integral with the turbine shaft. Any movement of this disc relative to the detector coils varies the air gap. The resulting change in inductance is measured, and provides an indication of any relative movement of the h.p. shaft. The equipment indicates and records axial differential expansion between the h.p. rotor and h.p. casing, shaft eccentricity and vertical or horizontal shaft displacement.

An electrical speed indicator and recorder is also provided, using a small high-frequency alternator driven from the turbine shaft through a specially designed quill coupling. The equipment is designed to give accurate information of the turbine speed during the running up period and during normal running or overspeeds.

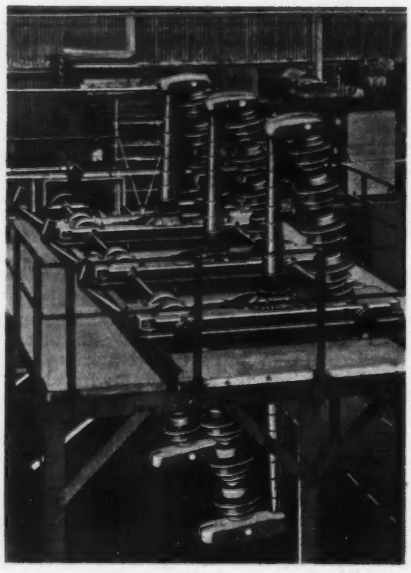


Fig. 8—132kV Isolator on Temporary Staging

There are separate indicating and recording instruments with two linear scales. The first scale covers speeds from standstill to about 2750 r.p.m., and the second, which is more sensitive, covers speeds from 2700 r.p.m. to 3300 r.p.m. The change from one scale to the other is automatic, the speed range on which the indicating instrument is operating being shown by coloured pilot lights.

The method of recording the temperature of the alternator rotor is based on temperature measurement by resistance. The ratio of rotor voltage and rotor current is indicated by a slow-speed motor-driven rheostat, which, under the control of a magnetic amplifier and relay, is used in a self-balancing circuit. The motor-operated rheostat and relay are housed in a single case arranged for switchboard mounting. The method of operation ensures that temperature indication is not affected by fluctuating load, the automatic voltage regulator or transients of short duration, while the degree of accuracy on full load is within ± 1 per cent.

Feed and Circulating Water Pumps

There are eight multi-stage boiler feed pumps; each is driven by a 1550 h.p. motor from the station 3·3kV supply. Any drop in pressure in the feed line, through electrical supply failure, causes two steam-turbo-driven pumps to start up automatically.

Feed water make up, amounting to about 4 per cent of the total steam consumption, is taken from the town's water supply, through softening and evaporating plant.

Circulating water is extracted from the river Usk by eight vertical spindle centrifugal pumps, each capable of handling 2,500,000 gallons of water per hour. Because of the large variation in tidal level (about 43ft), the circulating water pumps are each driven by a 1100 h.p. variable speed d.c. motor. The circulating water is discharged about 3000ft up river from the inlet. The outfall is designed to cascade, causing considerable aeration of the discharged circulating water, with the object of preserving fish life.

Auxiliary Supplies

Power supplies for the station auxiliaries are derived from two 132/3·3kV station transformers and from six 11·8/3·3kV unit transformers. Supplies for the coal and ash handling plant and other common services are fed from the station transformer and its switchboard; supplies for individual turbine and boiler plant auxiliaries are taken from the corresponding unit transformer and its switchboard. For starting-up and standby purposes, there are connections between the station switchboard and each unit switchboard.

Variable voltage d.c. supplies for the circulating water pumps and boiler fan motors are taken from grid-controlled mercury-arc rectifiers (Fig. 5), which are fed on the a.c. side at 3·3kV from the station or unit transformers.

Taking the fan motor control as an example,

on each boiler the two forced draught fans work as a pair and the two induced draught fans as another pair, their speeds being controlled automatically by servo units which operate phase shifters, and thus alter the voltages of the rectifiers supplying the motors. The output of the forced draught fans is thereby adjusted automatically to suit the combustion conditions, while the induced draught fan output is varied to maintain a predetermined suction in the boiler combustion chamber.

Main Switchgear

There is no switchgear on the 11·8kV side, each generator being connected to a 11·8/132kV transformer, and thence to the main 132kV switchgear, which consists of fifty-six isolators and twenty-one air blast circuit breakers. Normally, the 132kV switchgear would be outdoor equipment, but because of the heavy mists that are prevalent in the coastal district where the station is situated, it was decided to house the gear in a special building.

A conventional duplicate-busbar switching system has been adopted. A bus-section switch is provided in the main bars ; the reserve bars are normally sectionalised, but a reactor, controlled on each side by a circuit break and busbar selector switches, can be inserted either across the section of the main bars, or across the gap in the reserve bars.

The layout of the switchgear on three floors of the switch house is somewhat unusual. The circuit breakers and circuit isolators are mounted on the first floor of the switch house, with partition walls between circuits. The main and reserve busbars (Fig. 7) run the length of the second and ground floors respectively ; their isolator bases are on the second and first floors. By-pass isolators act laterally through the dividing walls on the ground floor.

In the centre of the building on the first floor are the control and relay rooms. The control room houses the main control board, the control desk for the six generators, the operator's desk and the control boards for the station auxiliaries.

The circuit breakers are Metropolitan-Vickers airblast " GA6S2 " equipments, but in this installation they are modified for mounting directly on the floor (Fig. 6) instead of on a support. This circuit breaker has a rated breaking capacity of 3500MVA at 132kV ; the total-break-time, measured from receipt of tripping impulse to final interruption, is approximately 3 c/s. There are two breaks per phase, each break being shunted by a " Metrosil " non-linear resistor. These resistors distribute the breaking duty evenly between the two series breaks and, in addition, they suppress the overvoltages liable to be produced during switching operations. Each break is housed in an " interrupter head," and a rotating " sequence switch " is connected between the two series breaks in each phase. At the end of the travel of the main contacts, which are nozzle shaped, compressed air is supplied to open the sequence switch, and is cut off from the interrupter heads ; the interrupters then reclose, and interruption is maintained by the sequence switch. To close or " make " circuit, the sequence switch only has to close. The compressor equipment is designed to supply compressed air at a pressure of 320 lb per square inch.

The isolators are specially designed to enable the two terminals in each phase to be in different rooms. For this purpose, the rotating contact blade has to be of a design similar to that of a bushing, so as to be able to pass through the floor or wall separating the two rooms. One of these isolators is shown in Fig. 8 ; in this illustration it is mounted temporarily on a raft, so that both sides are visible. When used to isolate feeders, these isolators are fitted with means for earthing the feeders. The sloping rods below, on the left, are the earthing blades that can be rotated into the jaws at the bottom of the insulator when the isolator has been opened. The bushings are shown taped for protection in shipping. The isolators are remote manually-operated from mechanism cubicles which, on site, are walled off from the live equipment ; each isolator is interlocked with its associated circuit breaker and access doors. The ring current-transformers are threaded over the cables or over the rotating blades of the isolators. The voltage-transformers are single-phase oil-immersed units with ratio 76,200/63·5V.

Testing connections are brought out from each bushing to a wall-mounted box in the operating corridor so that Schering Bridge insulation tests can be made on all bushings whilst in service.

Compressed air for the circuit breakers is obtained through a duplicate copper bus main from the compressor room on the ground floor and in the central portion of the building. The compressor room contains four compressors, two common air receivers divided into banks of four units, and a compressor control cubicle. The air pressure at the common receivers is reduced from 600 lb per square inch before entering the duplicate bus main so as to give a pressure of 325 lb per square inch at the circuit breaker unit receivers.

As much of the insulation on the switchgear is of bare paper, air conditioning of the switch building is necessary and steam for this purpose is provided from the power station. An air conditioning plant is in operation in the switch house which supplies conditioned air via sheet steel ducting to all parts of the building. The humidity and temperature of the air in the switchgear cubicles and busbar chambers is automatically controlled by electrically operated dampers at various points on the air ducting, whilst overall control is obtained by electrical operation of the steam supply valves to the air conditioning plant.

Connection to the 132kV grid is made by six outgoing feeders to Gloucester, Cardiff, Upper Boat, Lydney, and two to Llantarnam, with tee connections off these lines to Newport. The terminal towers are next to the building and connection from the switchgear to these is made by 132kV cables terminated in sealing ends installed in a compound. Isolation and earthing of these lines is carried out in the switch house.

Contractors

The main contractors for the power station plant were as follows. Turbo-alternators, G.E.C. Fraser and Chalmers ; steam raising plant, coal handling plant, ash handling equipment, Babcock and Wilcox, Ltd.; feed heating and condensing plant, Hick Hargreaves and Co., Ltd.; circulating water plant, Gwynnes Pumps, Ltd.; 132kV switchgear, Metropolitan-Vickers Electrical Company, Ltd.; 3·3kV switchgear, 415V switchgear, main lighting switchboard, The General Electric Company, Ltd.; subsidiary lighting switchboards, South Wales Switchgear, Ltd.; transformers and rectifiers, The General Electric Company, Ltd.; reactors, Hackbridge and Hewittic Electric Company, Ltd.; induced draught and forced draught fans and " Centicell " collectors, James Howden and Co., Ltd.; electrostatic precipitators, Sturtevant Engineering Company, Ltd.; electrically-driven boiler feed pumps, Mather and Platt, Ltd.; turbo-driven boiler feed pumps, G. and J. Weir and Co., Ltd. Civil engineering contractors—J. Morgan (Builders), Ltd.; Braithwaite and Co. (Structural), Ltd.; Holloway Brothers (London), Ltd.; Isca Foundry Company, Ltd.

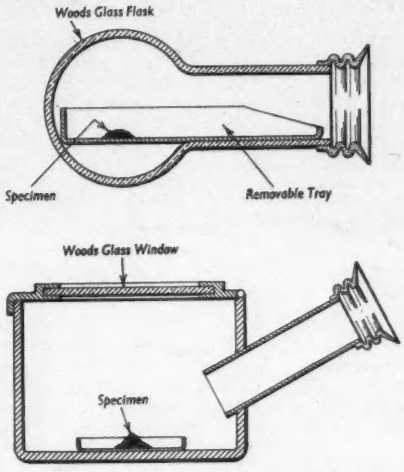
A Portable Fluoroscope

One of the accompanying illustrations shows a portable fluoroscope which makes use of ultra-violet radiation from daylight to detect the presence of fluorescent materials or to establish their identity. It is a self-contained instrument which does not require a battery or generator.

The new fluoroscope was devised by Mr. J. W. Walley, of the research department of Metropolitan-Vickers Electrical Company, Ltd., Trafford Park, Manchester, 17. Its operation depends primarily on the fact that sunlight contains a useful proportion of ultra-violet : a daylight-absorbing but ultra-violet transmitting filter, such as that known as Wood's glass, is used to provide ultra-violet radiation for viewing the fluorescent material in a closed compartment. A fluorescent material then glows at a longer wavelength of visible light, this wavelength being characterised by the nature of the specimen.

In its simplest form a fluoroscope operating on this principle was made by adapting the Wood's glass flasks used as light-excluding envelopes in the manufacture of the standard mercury-vapour discharge lamps, as shown in the upper sketch. The neck formed a convenient hand grip without obscuring the bulb, and a rubber eye guard was fitted around the opening to exclude visible light when viewing. The diameter of the spherical bulb was about 3·5in and the thickness of the glass was about 0·03in. To facilitate insertion and extraction of the specimen without contamination of the bulb a removable tray was provided.

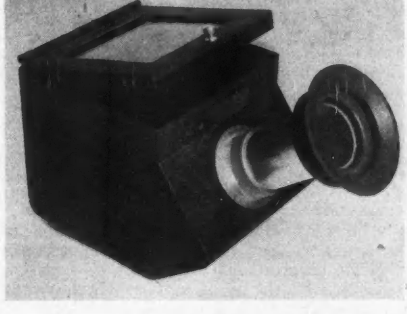
A more robust instrument is shown diagrammatically in the lower sketch. It consists essentially of a steel box about 5in cube with a hinged



Principle of Glass Flask and Box Fluoroscopes

window of Wood's glass at the top and an eyepiece tube entering the front side obliquely. The hinged window serves as an ultra-violet filter and insertion door combined. The inspection tube is adjustable to maintain the specimen in focus, and a rubber eye guard is again used for comfort and visible light exclusion. The Wood's glass in the window is about 3in square and about 0·2in in thickness. A photograph of this apparatus with the hinged window slightly open is reproduced herewith.

Although the all-glass design may be regarded as rather fragile to be readily transportable, no trouble was experienced in making tests with markedly fluorescent materials such as anthracine powder, engine oil and vaseline. In each



Portable Fluoroscope with Hinged Windows

case the characteristic fluorescent glow was easily observed when the fluoroscope was activated by normal daylight, thus establishing the basic principle of daylight fluorescent viewing.

Good results were obtained with the above materials when testing indoors under a skylight or by a window, even on a dull day, but the best results were obtained with direct sunlight. For instance, with sunlight a faint fluorescent glow was observed from a wooden matchstick, which was presumably paraffin-impregnated during manufacture. Tests with specimens of this kind showed the importance of excluding all visible light and of allowing a few seconds for the observer's eye to adjust itself to the darkened interior of the fluoroscope. Tests were also successful under artificial light from electric lamps of both the metal filament and the fluorescent tube types. Contrary to expectations,

the difference in thickness of the Wood's glass used in the fluoroscopes caused no noticeable difference in the transmission of ultra-violet.

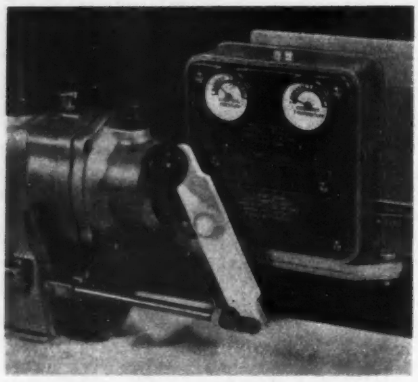
These tests suggest that some of the fluorescent inspection that is done at present with electrically produced ultra-violet rays would probably be quite satisfactory with natural ultra-violet irradiation using the apparatus described here. This fluoroscope can be used anywhere where a reasonable degree of daylight is available, though strong sunlight is preferable. It is independent of electrical supplies, but it can also be used where either metal filament or fluorescent electric lighting is available.

The manufacturer points out that it should be possible to increase the sensitivity of the box fluoroscope where direct sunlight is available : this refinement would entail the use of a convex lens suitably focused and mounted above or below the window to produce a concentrated spot of ultra-violet light as distinct from the even distribution of the window above. Alternatively a hinged lens of Wood's glass might function as a combined ultra-violet filter, focusing lens and entrance door.

Oil Engine Protection Units

PARTICULARS have been received from Teddington Industrial Equipment, Ltd., Sunbury-on-Thames, Middlesex, of two recently introduced protective devices for diesel engines. One of these devices is electrically operated and the other is for use where no power supply is readily available.

The non-electric protective device is illustrated below. It consists of a latched throttle lever, for attachment to the fuel pump, which is normally spring-loaded in the throttle-closed position. When the engine is started this lever is



Non-Electric Oil Engine Protection Unit

latched in the engine running position against the spring load. Two alternative controls are provided. One is pressure sensitive and suitable for attachment to the lubricating oil pressure connection, and the other is a thermal assembly with 5ft of protected capillary tube connected to a sensitive feeler which is inserted in the cooling water circuit by means of a screwed bulb pocket. When the engine is running and oil pressure and water temperature are normal, the unit does not interfere in any way with the operation of the normal governor setting on the fuel pump. If, however, the water temperature rises above or the oil pressure falls below a predetermined safe limit, the latch is disengaged and the throttle lever moves under the influence of the spring to the shut-down position, thus stopping the engine before any serious damage can occur.

The fault indicator system gives the operator the reason for the shut down. This device consists of two indicator dials, each marked " normal " and " danger," and suitably coloured. When conditions in the lubricating oil and coolant system are normal each pointer remains in the appropriate sector of the dial, but if the pressure falls below or the temperature rises above the predetermined danger point the appropriate pointer moves over to the danger side of its dial and the throttle lever is tripped automatically. This operation freezes the indicators so that the indication just prior to shut down can at once be seen. On moving the throttle lever to the running position the indicators are automatically reset.

An automatic mechanism which is fitted enables the engine to be started even though at the time there is no oil pressure available. This device is arranged to set the automatic operation once the oil pressure has risen to the normal running level, after which the device is entirely automatic and will stop the engine if the oil pressure falls at any time below the predetermined safe working level.

In the electrically operated device the stopping of the engine can be effected either by a solenoid - operating throttle lever or by solenoid valve in the fuel supply. The solenoid - operated throttle lever control consists of a lever arm for attachment to the throttle control lever on the fuel pump. This arm is normally spring-loaded in the throttle closed position and it is held against the spring by a latch in the engine running position. When the solenoid is energised the latch is tripped to stop the engine. A switch disconnects the solenoid coil after operation to prevent unnecessary battery discharge through the solenoid during the standing period.

A solenoid-operated fuel valve is arranged to be de-energised and shut off the fuel supply to stop the engine when the danger point is reached.

A Hydraulic Jack for Prestressed Concrete

A LIGHTWEIGHT hydraulic jack has recently been developed for prestressed concrete construction. The jack is used to tension the wires of a prestressed concrete unit individually, for any size of wire up to 0·276in in diameter. It has been developed jointly by Mr. E. W. H. Gifford and the J. J. Udalls Building Company, Ltd., of Southampton, in collaboration with Cable Covers, Ltd., of Westminster, whose system of anchorage grips is used with the jack.

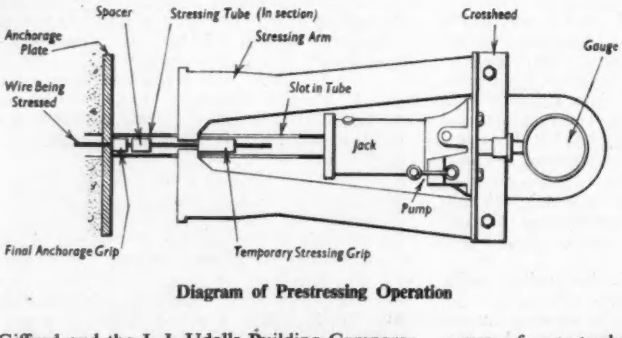
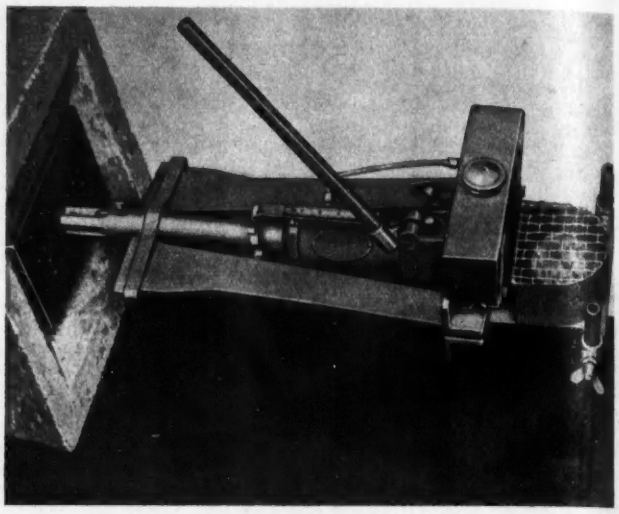


Diagram of Prestressing Operation

The anchorage grips, which have been in use for some time for the pretensioning of factory-made prestressed concrete units, consist basically of a collar which runs loosely on the prestressing wire, and two wedge-shaped cotters with serrated grip surfaces adjacent to the wire, which are tapped into the collar on each side of the wire to effect the end anchorage. These anchorage units are described in the *National Building Studies Bulletin No.* 12, published by H.M. Stationery Office.

The method of operating the jack is shown in the diagram. The final anchorage grip of the wire which is to be tensioned is placed in position with the cotters inserted lightly in the collar, and a second collar, which acts as a spacing piece is inserted on the wire next to the first. A temporary stressing grip, which is similar in principle to the anchorage grip but is spring-loaded so that it will grip the wire without any slipping, is then fixed on to the wire a given distance away from the spacer. The stressing tube of the jack—a slotted



Hydraulic Jack for Prestressed Concrete

tube which bears against the mild steel anchorage plate—is then placed over the wire and the two stressing arms are closed through the slots in the tube so as to bear on to the stressing grip. The final anchorage grip and spacer are held in position by a wedge, fitted through a slot in the stressing tube. The photograph reproduced below shows the two stressing arms locked in position with the wedge inserted in the top of the stressing tube. This illustration also gives an idea of the general construction of the jack.

With the jack in position, the required tension is obtained with the hand pump of the jack, as measured either directly, as extension of the wire, on the scale attached to the jack, or on the pressure gauge. The two cotters of the final anchorage grip are then tapped into position to anchor the wire. The wedge is removed to do this, and a special tool which fits through the wedge slot is inserted and tapped with a hammer to fix the cotters in position. Having thus anchored the wire, the pressure on the jack is relieved, and the stressing arms uncoupled.

The makers state that extensions of up to 4½in may be obtained with the standard jack, but alternative forms can provide up to 14in extension. The wires may be arranged in groups of up to twelve wires in one duct, for post-tensioned work. Spring-loaded grips may be used for anchoring the wire if future extension is anticipated. With the normal anchorage grip described above, it has been found that a slip of ¼in occurs consistently when tensioning, and so ¼in must be added to the calculated figure for the extension of the wire. The entire jack unit weighs 56 lb. It is claimed that one man can tension and anchor wires at the rate of twenty an hour with this equipment, after about an hour's instruction.

ENGINEER OFFICERS IN THE MERCANTILE MARINE.—The examination centre in London for candidates for certificates of competency as engineer in the Mercantile Marine has been moved to 58–60, Moorgate (Fifth Floor), London, E.C.2, and all examinations will now be held at that address.

Pass-Out Generator Sets at Coryton Refinery

We have received some details of the three pass-out turbo-generator sets which have been supplied, for the Coryton refinery of the Vacuum Oil Company, Ltd., by Metropolitan-Vickers Electrical Company, Ltd. A point of interest about the generators is that the air coolers are mounted longitudinally on the outer periphery of the yoke instead of being built into the generator foundations.

Each of the three sets is rated at 5000kW at 3000 r.p.m. The single-cylinder turbines are supplied with steam at 600 lb per square inch gauge, 735 deg. Fah., and are designed to pass-out steam at 140 lb per square inch gauge and 20 lb per square inch gauge ; under certain conditions provision is made for steam at 20 lb per square inch gauge to be passed-in to the turbine. The staging of each turbine consists of a velocity compounded stage and ten single high-pressure stages before the 140 lb per square inch gauge pass-out belt, six single intermediate-pressure stages between the pass-out belts and, after the second belt, a velocity compounded stage and four single low-pressure stages.

Admission of steam to each turbine is controlled, through the medium of an oil relay system, by a vertical centrifugal speed governor ; four steam admission valves in the high-pressure steam chest, which is integral with the top half high-pressure end of the turbine casing, are made to open or close in sequence as the steam load increases or decreases. Control of the pass-out pressure of the steam at each of the two points in the turbine expansion is effected by a rotating disc valve. The disc valve is positioned by a double-acting oil-operated power piston, which in turn is controlled by a pilot valve directly connected to a flexible spring-loaded metallic bellows supplied with compressed air from the Bailey pass-out control system.

The Bailey control system consists of a series of air operated relays and a master pressure controller connected to the pass-out steam line. An increase in steam pressure in the pass-out line causes an increase in the control air pressure in the metallic bellows, consequently the disc valve opening is increased and more steam is admitted to the turbine stages positioned after the disc valve ; conversely a reduction of steam pressure in the pass-out line causes a decrease in the control air pressure, the disc valve opening is reduced and more steam is passed-out of the turbine.

Under certain conditions it is desired to pass steam into the turbine through the 20 lb per square inch gauge steam line ; the pass-in steam is controlled by a low-pressure governor valve, the opening and closing of which is determined by the speed governor through the medium of a sensitive oil transmitter and a receiving unit. The oil transmitter ensures that, with falling speed, the low-pressure governor valve opens before the steam admission valves and closes after them with rising speed, therefore, under normal operating conditions when one or more steam admission valves are open, the low-pressure governor valve is at maximum lift. An emergency stop valve, which is situated with the low-pressure governor valve in a chest adjacent to the turbine, closes automatically should the overspeed governor function or if, for any reason, there is a loss of relay oil pressure.

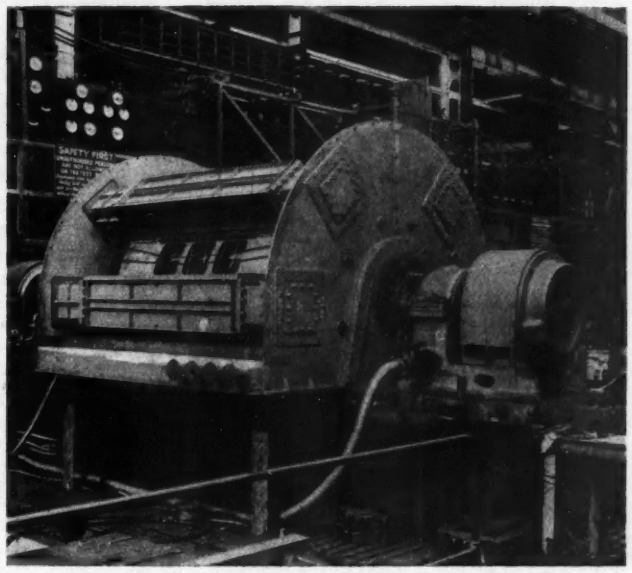
The turbines exhaust into Metropolitan-Vickers single-shell, central-flow condensers. Each condenser has a cooling surface of 6000 square feet, and the cooling water is constrained to follow a two-flow arrangement through the tubes.

Each of the three a.c. generators has an output of 6250kVA (0·8 power factor) at 11kV, three phase, 50 c/s. These machines are of particular interest because of the ventilation and cooling system, which is of unusual design. As is normal with this size of generator, they are equipped with a closed circuit air ventilating system, but whereas the customary arrangement is to mount the air coolers below the generator in the foundations the Coryton generators have the air coolers mounted longitudinally on the outer periphery of the yoke.

There are four air coolers on each generator built up from tubes through which the cooling water circulates. These coolers are fitted on the machine frame (as shown in one of our illustrations) and the air circulated by the rotor fans passes through ducts in the stator punchings over the windings, through openings in the frame and over the water cooled tubes. A sheet steel casing is fitted round the stator outside the cooler to give the necessary air-tight enclosure. Cooling water is led to and from the coolers by pipes each side of the base of the generator at the exciter end as indicated in the photograph, which shows one of the generators being prepared for test.

Otherwise these generators are of the company's standard construction. The 11kV stator winding is of involute form and the stator frame is of welded construction with a core built of silicon steel laminations. The direct-connected exciters have radial commutators and the generator rotor has two sliprings of tool steel mounted on the shaft inside the bearing.

3,000kW Pass-out Sets in Coryton Refinery Power Station



Generator and Cooling System Erected for Works Test

Iron and Steel Institute.—The twenty-third meeting of the iron and steel engineers' group of the Iron and Steel Institute will be held at 4, Grosvenor Gardens, London, S.W.1, on Wednesday, October 28th, beginning at 10.30 a.m.

Construction Programme of the Bureau of Reclamation

The U.S. Bureau of Reclamation has announced that during the current fiscal year, from July 1, 1953, to June 30, 1954, it intends to undertake a construction programme involving the expenditure of 174 million dollars. The programme aims to provide irrigation water for 248,194 acres of land and to install 297MW of hydro-electric generating capacity. In addition to the goals set for the current fiscal year, the construction work to be undertaken will enable the Bureau of Reclamation to complete irrigation facilities to serve 385,227 additional acres in the fiscal year 1955 and 228,377 acres in the fiscal year 1956. The programme also contemplates the installation of 242MW of generating capacity in 1955 and 12MW in 1956. Of the land for which facilities will be completed during this fiscal year, 139,714 acres are at present irrigated, but with an inadequate supply which will be supplemented by the new construction. The bulk of this supplemental service will be on the Colorado-Big Thompson project, which will be ready to serve an additional 122,000 acres by next year.

The Columbia Basin project, in Central Washington, which already has facilities for the irrigation of 131,000 acres of new land, will add facilities for the irrigation of another 55,000 acres by the end of this fiscal year and has scheduled the completion of facilities for the irrigation of another 61,000 acres of new land in each of the succeeding two fiscal years. All publicly owned land or land which is purchased by the Government on this project is offered for resale in family-size farm units as rapidly as water becomes available. Additional lands for public settlement will also be made available on the North Side pumping unit of the Minidoka project in Southern Idaho and on the Gila project in South-Western Arizona. The last two of the four generators at the Hungry Horse dam in Montana were installed in July of this fiscal year, bringing the hydro-electric plant at that important unit of the Columbia Basin system to its full capacity of 285MW. Ground will be broken shortly on an entirely new scheme, the construction of the Monticello dam on the Solano project in California. Finally, the current fiscal year will also bring about greater progress on the Eklutna power project near Anchorage, Alaska. The present Congress approved an enlarged authorisation which was necessary to complete the project and supplied funds to permit construction to go forward at an accelerated rate during the present fiscal year. The 30MW power station and the transmission lines are now scheduled for completion during the fiscal year 1955.

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BRITISH ELECTRICITY SUPPLY

The annual report of the British Electricity Authority, to which we referred briefly in last week's issue, does more than review the year's progress for 1952–53: it marks the end of the fifth year since the industry was nationalised and it provides enough statistical material for some assessment to be made of five years' progress under unified control. In those five years the sales of electricity to consumers have increased by 47·3 per cent, but the increase recorded in the last year was only 3·7 per cent, compared with an average annual increase of more than 9 per cent. The drop in the rate of growth during 1952–53, however, was mainly a result of the recession in the textile trade and other causes which may be regarded as transitory. Indeed, the latest figures published by the Authority show that in August, 1953, the sales of electricity were 9·3 per cent more than in August, 1952. These figures suggest a return towards a 10 per cent annual rate of development which can properly be regarded as normal and healthy. There is some cause for satisfaction, too, in the fact that the combined revenues of the B.E.A. and the Area Boards exceeded their combined expenditures in 1952–53 by £7,280,823, and that the total surplus for the five years since vesting day is £28,331,757. These apparently handsome "profits" are seen to be quite modest when they are viewed against the current expenditure on revenue account of £284,000,000 and assets having a gross book value of £1,436,860,000.

On the engineering side it is encouraging to learn of the rapid rise in the rate of installation of new generating plant from 340MW in 1947 to 566MW in 1948, 965MW in 1950 and 1539MW in 1952. Last year the amount of new plant installed was, for the first time, substantially in excess of the B.E.A.'s "optimistic estimate." These figures of plant newly commissioned are, of course, of more than academic interest for, despite the progress made, particularly in the past two years, there is still a substantial deficiency in the total available generating capacity. The shortage, at the time of maximum potential demand was, in fact, estimated at 1549MW, compared with 1192MW for the previous year. These values, however, take no account of weather and load spreading and it is estimated that, if the weather had been very cold and if no load spreading arrangements had been made by industrial and commercial consumers, the shortage would have been 2400MW in 1952–53 and 2550MW in the previous year. The real danger, as visualised by Lord Citrine at a press conference in London last week, is more likely to come in five years' time, than now. He thought that in the coming winter there would be enough generating capacity to do without compulsory load spreading, but that the gap between supply and demand was likely to increase to a serious extent by about 1958. The basis for this apparently pessimistic forecast is that the "realistic estimates" made by the B.E.A. for its construction programmes have been scaled down too much by the Government. However, assuming that the realistic estimates are reasonably accurate, it is difficult to believe that a serious deficiency could be caused by reducing the new plant authorisation for 1958, for example, from 1800MW to 1750MW. Nevertheless, if it is felt that these restrictions are likely to result in a serious shortage of plant in six or seven years' time, the B.E.A. is fully justified in making representations now, while there is yet time to apply a remedy.

On the subject of technical progress, there is not very much to be added to the information contained in the Authority's previous annual reports. We learn that the overall thermal efficiency of the B.E.A. steam power stations has improved steadily from 20·87 per cent in 1947–48 to 22·04 per cent in 1951–52 and 22·72 per cent in 1952–53. These improvements, though they may appear small, assume significant proportions when it is recalled that they represent a saving of about 7¼ million tons of coal since vesting day. Further gains are still to be won as the installation of new plant in increasing quantities allows more and more old and inefficient plant to be shut down. Among the new installations now in the design stage are Willington "A" station (Derby), which will incorporate 100MW generating sets, using a 1500 lb per square inch, 1050 deg. Fah. straight cycle, and the Blyth and Drakelow "B" stations, which will house 120MW sets using steam at 1500 lb per square inch at 1000 deg. Fah, reheating to 1000 deg. Fah. More spectacular results may be sought from the extended use of pass-out turbines, with district heating but, except for developments on a limited scale, the cost is likely to be prohibitive. The Pimlico scheme, for example, showed an overall efficiency last year of 81·6 per cent on the heat and electricity account, but the B.E.A. report suggests that it is too early to judge the economic and technical merits of the scheme. Progress on two interesting transmission developments are referred to in the report: the 275kV grid and the cross-channel cable, which has reached the stage where trial lengths of cable are undergoing sea tests. Both schemes will promote the more effective use of limited generating resources, first in Great Britain and secondly between Great Britain and France. The 275kV grid is already taking shape and the initial connection between Staythorpe and West Melton is in operation: the cross-Channel cable is an imaginative venture, the progress of which will be watched with interest at home and abroad.

PRESERVATION OR ENHANCEMENT

It is a commonplace experience of engineers that determined opposition is offered to many of the greater schemes they devise for the benefit of mankind. Let it but be suggested that a dam or a bridge be thrown across a river, a new road be built, or a new industrial works be erected and a clamour of dissent breaks out. Much of the opposition is reasonable enough. Many of those who dwell in the area may fear their interests will suffer. But through discussion, negotiation and modification that opposition can usually be appeased. But there is one form of opposition that is generally inappeasable; for it seeks neither financial recompense nor modification of design. It is convinced that no such engineering structure should be erected at the particular site. Again reason is sometimes upon the side of those who hold such views, as, for example, when some industrial building such as a gasworks or a power station is proposed to be built in a predominantly residential area within which, however admirable the site in other ways, it would be anachronistic. But it is not always so. More often it is held that the engineering structure or the industrial works will "desecrate" the natural scene. Such opposition is sincere and all the fiercer that in every other respect it is disinterested. But very often it is as mistaken and reactionary in our day as the opposition aroused amongst landlords and others against the advent of the railways.

In particular, to-day, opposition is fiercely offered to the development of areas within National Parks. Let it be said at once that our sympathies are wholly with those who have urged the setting aside of certain areas of this country as places of such high beauty that especial efforts should be made to

prevent defilement. It should be admitted, too, that there are certain kinds of industry and certain forms of engineering structures that ought not to be permitted to find a place in those areas. But that is very far from suggesting, as some of the protagonists of National Parks seem to suggest, that all development should cease ; that those parks should for evermore remain unaltered, and that there should be no change in the uses the land is put to. The purpose of the National Parks is not only the " preservation," but also the " enhancement " of natural beauty, and the accent should not be laid, as some of their protagonists do lay it, only upon the former. The basic supposition of those who oppose changes is that the " natural " state of the park ought not to be altered. But, in fact, is there any land in this country which is truly still in its " natural " state ? Has not nearly all of it been put to use of one kind or another and been tilled, fenced, cleared and enclosed for that purpose ? The typical English landscape is no more " natural " than are the works of engineers. It is man-made to serve man's purposes. In the past men cleared the natural forests, drained the natural marshes, planted woods and forests, grew hedgerows and built walls. They embanked rivers and dammed streams to operate waterwheels and to irrigate water meadows. They built tracks and roads, and bridges to carry them over streams and rivers. They constructed canals, viaducts and railways. A few of those works certainly did not improve upon Nature. Yet it is astonishing how very large a proportion added to the attractions of the country scene ! Throughout history the scenery has changed to accord with changed agricultural methods, altered rural activities and economic circumstances which at different eras have favoured particular ways of utilising land. To check back the development of National Parks to the particular stage of development reached at the present time would be not to " preserve," but to destroy, to withhold from those who live in such areas the benefits of advancing civilisation that others enjoy and to lay upon them ultimately that same evil of depopulation that afflicts the islands and Highlands of Scotland.

In our view emphasis in the National Parks should be laid upon the " enhancement " of beauty, not merely its preservation ; they should not be embalmed, but embellished. There will always be argument as to what does and what does not enhance beauty. Yet who can doubt, who looks around, that a great many of the modern works of engineers have added as much to the attractiveness of the English scene as did their more ancient ones ? Have not reservoirs created for hydro-electric or water supply purposes become, often, beauty spots ? Is there no æsthetic pleasure to be gained from seeing a well-designed concrete bridge spanning a mountain torrent or the modern road which emphasises by its sweeping upward line the contours of a valley side ? There is even more than a little to be said for modern industrial works so long as they be naturally sited in the area concerned through depending upon its products as raw material. Destructive fumes need not come from chimneys ; the waters of the local stream need not be polluted, nor need the buildings be other than attractive. Even the quarry and the mine are not necessarily unsightly. All bring useful activity and prosperity to the area. In our view, indeed, far from wholly barring further industrial development within National Parks, the endeavour should be made to show within them how by making intelligent and careful use of what those areas provide, whether it be water power, agricultural and forest products or geological deposits, and by admitting to them industries suited to their natural advantages, their beauties can be enhanced. For though the protagonists of " preservation " hope by that means to save the National Parks from desecration, those areas have enemies far more than engineers and industrialists. In the last twenty years far more fine scenery has been spoiled by unsightly advertisements, litter, the erection of shanty tea-houses and ice-cream parlours, the opening of shops of knick-knacks and mementoes, the building of gaudy petrol stations and the like paraphernalia for making quick, easy seasonal money out of tourists and trippers than was ever effected by the erection of engineering structures or the operation of industrial works.

Letters to the Editor

(We do not hold ourselves responsible for the opinions of our correspondents)

THE ROLE OF EXPERIMENTS IN APPLIED SCIENCE

SIR,—Your review of Professor Pippard's " Studies in Elastic Structures " and his own letter on the subject, in your issue of September 18th, encourage comment on the general question of the need for experimental work in engineering. In a broad and perhaps rather flippant sense every new engineering design is an experiment, as small departures from convention may have disproportionately disastrous results. If the product (a machine or structure of some kind) is used by its manufacturer, the manufacturer does the experiment. If he sells it to a user, then the user does the experiment. There is nothing essentially unethical about this, as the only reliable experiment may be actual use, nor is it certainly wrong for the user to be allowed to do the experiment unwittingly, as use under specially observed conditions may give a misleading idea of what is likely to happen in normal service. (A locomotive superintendent once said that blue painting the chimney of any locomotive would reduce its coal consumption by at least 10 per cent, because its distinction would suggest that it was under special observation and so induce the men to work it properly.)

Acceptance of the principle of experiment by the user becomes easier when it is reflected that where very large plant is concerned no other course may be possible ; experiments on a model are useless where the main experimental feature is that of size. None of the three manufacturers of boiler, turbine and alternator in a large electric power generating plant may be able to experiment on his own product because of lack of equipment for producing or dissipating the power to be handled. Experimental features in any one of the main components can be thoroughly tested only when all three are brought together, and this may be impracticable anywhere but on site. It may be argued that as separate experiment is impossible where it would be most valuable, why consider it in any case ? There is some force in this where a " one off " job is concerned, but when quantity production of a small item is contemplated, then preliminary experiment by the manufacturer is practicable and financially justifiable. These remarks refer, not to a product of completely experimental character, but to one of accepted general design but with experimental features. Anything entirely or largely novel will be recognised as such by the user, who will either agree to use it to the best advantage whilst allowing experimental data to be gathered from it, or will insist on thorough tests before he takes it over.

Tests on any plant in service are likely to be useful, but unlikely to produce as much information as if they were run in conditions devised solely to facilitate experimental work. Consequently it is technically preferable, where commercially possible, to carry out experiments on a pilot model, or even on the actual product before setting to work. If it is expected that the experiments will produce information useful in design of many subsequent items of generally similar character, then they may justify the building of plant solely for experimental purposes if the alternative of calculation is impracticable or deemed to be unconvincing. An example of this is the classic series of tests made by Professor Goss, of Purdue University, with the object of determining the best proportions of the draught-producing elements in a locomotive smokebox. It is safe to say that no one suggested that that end could be achieved by calculation and, judging by the variety of designs actually used before (and since) the publication of the Goss results, few designers approached it by guesswork. Recommendations based on examination of the observations made on the performances of many different combinations of important dimensions, were expressed in simple working formulæ for designers. This therefore was a case of carefully controlled experiments on a machine reserved for the purpose with the object of rationalising the method of design of a fundamentally important feature of the steam locomotive. Another example of observations made to discover design data is the measurement of twist in a multi-throw crankshaft under known torque. The figures thus determined for torsional stiffness are used to estimate the values of certain constants in a stiffness formula of rational algebraic character. A knowledge of the torsional stiffness of the crankshaft is required in predetermining the critical speeds for torsional vibration. More recently, bending stresses produced by crankpin loads have been systematically measured by strain gauges with the similar object of establishing formulæ by which the maximum stresses in any crankshaft of reasonably similar design may be calculated with a satisfactorily small tolerance.

An overdue experiment might be carried out to show (if possible) by direct test whether there is rational justification for the use of the present British Standards formulæ suggesting that the permissible loading of the working surfaces of gear teeth is proportional to the 0·8th power of the radius of relative curvature of the contacting surfaces. The British Standard practice is based on the results of examining service records of a large number of gears of different materials and sizes, but it does not apparently agree with either the Herz stress analysis for dry surfaces or with the result of the Martin fluid pressure analysis for lubricated surfaces. The British Standards formulæ for load capacity of gears are irrational in several different ways, but nevertheless the results they give when applied to the majority of gears of not abnormal dimensions are not dangerously or inconveniently misleading. The value of conducting a series of experiments to test any proposed rational system may therefore be questioned by anyone who uses gears for transmitting power and not merely as a topic for academic discussion. If gears are to be made in quantities for specially exacting duties, e.g. aircraft service, where expense is secondary to saving in weight, it is valuable to conduct experiments on pilot pairs. This is a case of " testing " rather than experimenting, except that it affords opportunity for investigating

the effect of changing the amount and character of profile modification of the teeth. This feature has a great influence on the maximum stresses induced in spur gear teeth, and although the effect may be estimated with fair accuracy for any assumed value of the profile modification, direct confirmation is clearly desirable where variation of a few ten-thousandths of an inch in tooth form may be vital.

Engineers are naturally reluctant to rely solely on the results of calculation in critical cases, particularly where experimental verification costs only a small fraction of the total profit to be expected if a successful design is achieved or of the possible losses if it is not. Here perhaps is the crux of the matter in commerce as distinct from science. By how much will knowledge of the result of the experiment reduce the probability of failure in the design approved in the light of that knowledge ? Does the responsible engineer think that the economy by the probable reduction in failures will be greater than the cost of the experiments in money and time ? The answer depends, as so frequently it does, on the psychology and experience of the individual. He may fear to suggest to those who matter to him that he lacks complete confidence in himself, and open experiment may do just that. He may decide, as Edison once did, that " he can guess nearer than the mathematicians can figure " ; he may feel confident that what looks right to him on the drawing board will work satisfactorily in practice ; or he may tell himself that even if it does not, he can evade serious consequences.

W. A. TUPLIN
Professor of Applied Mechanics
University of Sheffield,
September 26th.

SIR,—So far as the discussion between your reviewer and Professor Pippard has gone there appears to be a difference of opinion only on the value of experiments which reproduce the simplifying assumptions of the mathematical analysis they are designed to check, which, with an exception in favour of teaching, your reviewer considers of questionable value. He suggests, as for example, that a scale model frame test would be more informative than a test on a pin-jointed model frame if the full-sized prototype is not in fact pin jointed.

I submit that it is an over-simplification of the position to suppose that we can make a model which is absolutely representative of either the analytical assumptions or of the prototype. In all engineering problems the most careful attempt to reproduce the analytical abstractions is limited by the nature of real materials, and in particular by size effects and lack of homogeneity, by our inability to reproduce such items as the frictionless pin joint without initial clearance or permanent set due to localised loading, and by the effect of approximations in the mathematical treatment. Until it has been established that the simplified model gives results in close agreement with the analysis it is not possible to understand the discrepancies which may be found with more representative models or on the prototype.

There is a further point which requires emphasis : engineering is still to a not inconsiderable extent an art. There is a disturbing tendency abroad to assume that all engineering problems are capable of exact analytical solution, and that not only are the results of such analysis valid without physical checks, but that any problems not so soluble are not engineering. I contend that experiment is essential in all four of Professor Pippard's categories : exploratory, confirmatory, for the production of data or to replace computation in specific problems. Why should it be thought almost immoral, verging on cheating, to avoid difficult analysis by well-planned experiment to use dial gauges rather than differential operators ? Personally, I would sooner trust the results of the trial and would be unwilling to pin too much faith in the analysis until checked by experiment on model or prototype.

EWEN M'EWEN
University of Durham,
September 26th.

JET TRAINER POLICY

SIR,—I was interested to read your article on the S.B.A.C. flying display and static exhibition in your issue of September 4th. On page 310 of this issue, when discussing the Armstrong-Siddeley " Viper " A.S.5 engine, you mentioned that it was being produced for the Percival Provost " intermediate " trainer aircraft. I would like to draw your attention to the fact that this is not an intermediate trainer. The intermediate training aircraft were dropped in 1946, when the policy for R.A.F. flying training was changed. Prior to that there were three stages of training—elementary, intermediate and advanced. Now there are only two stages—basic and advanced.

The Percival " Provost " powered by a 550 h.p. Alvis " Leonides " piston engine is the present basic trainer of the R.A.F. A project based on this aircraft has been developed as a private venture by the company to take a jet engine, namely the " Viper " A.S.V.5, as it is considered that future training policy of the R.A.F. is likely to develop on these lines. The company's initiative has been recognised by the granting of a contract for the construction of these " Jet Provost Basic Trainers " for the R.A.F., who will assess from them the future policy of the R.A.F. flying training.

Y. GALITZINE
Hunting Group Public Relations Officer
London, W.1.

Management and Mechanisation

ON Wednesday of last week a conference was held in London on the subject of " Management and Mechanisation." It was arranged jointly by the Association of Agriculture and the British Institute of Management and resulted from the success of a similar conference held about a year ago when the subject discussed was " Management in Industry and Agriculture." Those participating in the conference last week included representatives of the engineering and other industries, farmers with considerable experience of agricultural mechanisation, and a number of representatives of the agricultural machinery trade. The particular value of the conference was that it enabled some useful comparisons to be made between the effect of mechanisation on manufacturing industry and on agriculture.

Sir Patrick Laird, formerly Secretary to the Department of Agriculture for Scotland, presided over both the morning and afternoon sessions of the conference. At the former the " human problem " was discussed, the general question submitted to the conference being " What are the implications of mechanisation as far as labour is concerned ? " The question was dealt with, on behalf of agriculture, by Mr. A. S. Rickwood, of Chatteris, and, for industry generally, by Mr. B. Ungerson, who is the personnel director of the John Lewis Partnership, Ltd. At the afternoon session consideration was given to economic problems, and in particular to the way in which the drive towards mechanisation works out in practice. The first speaker was Mr. B. G. L. Jackman, works director of British Heat Resisting Glass Company, Ltd. He emphasised that increased mechanisation now made possible many things which twenty or thirty years ago would have been considered impossible on the grounds of the time factor or of expense. Mr. Jackman said that such things as high quality in large quantity production. more portable or semi-portable power tools to assist the heavier manual jobs, more accurate and rapid methods of gauging and inspection, improved methods of storage and packaging, and many other milestones of progress were the direct outcome of increased mechanisation. One plea put forward by Mr. Jackman was that men should be trained to do more than one job proficiently and should be encouraged to look upon increased output as a craft. He also advocated that management should train younger men to take over routine matters whilst applying the experience and knowledge of older executives to new methods and processes. Mr. Jackman went on to stress the importance of the conservation and full utilisation of materials, in which, he said, mechanisation was helping, and he urged that machines and equipment should be used at least eighty hours a week, earning annually at least one-third of their initial cost. Finally, Mr. Jackman suggested that the practice of work study should be encouraged, irrespective of the product or class of factory.

Mr. John Rowsell, a farmer member of the council of the Institution of British Agricultural Engineers, spoke for agriculture. He felt that if full advantage was to be taken of agricultural mechanisation in this country, specialisation on farms was essential, but the danger of that was that it would of a necessity bring about lower overall production. Mr. Rowsell then went on to talk about some of the problems of mechanised farming. He said that during the war, as a result of prevailing shortages, and afterwards as a result of fantastically increasing costs, repairs became a most serious problem. That problem was tackled by various methods, but, Mr. Rowsell commented, what surprised him was that those who set up their own workshops and imported expert mechanics from the towns, the services and elsewhere, still seemed to be in as much difficulty as before ! The problem there was that the farm machinery mechanic must first of all know all about farm work as well as farm machinery. Other points made by Mr. Rowsell related to spares for machines and implements, to the equipment of farm workshops, and to the problem of grain storage. To them, he added the observation that electricity was one of the greatest assets to the agricultural community and one which was not used to anything like the extent to which it should be. Finally, Mr. Rowsell expressed the view that standardisation of equipment remained one of the great problems of mechanised farming. Several people, he said, had achieved standardisation by using one make of tractor but he felt that they missed some of the benefits of a variety of power units. With the manufacture of several successful diesel tractors in this country, however, much more standardisation was possible, particularly as many of them were available with tracks as well as steel wheels or rubber tyres.

Between the conference sessions, there was a luncheon at the Park Lane Hotel, at which Sir Hugh Beaver, chairman of the British Institute of Management, presided. After the luncheon, the company was addressed by the Minister of Labour, Sir Walter Monckton, Q.C., who urged that there should be no halt in the progress of mechanisation applied to agriculture. He said that foreign buyers were attracted to those sections of the engineering industry whose products were used to advantage at home, and there was probably no exporting industry which could be in a healthy condition unless it was based on a firm home market. Britain had become one of the most highly mechanised countries in the world in proportion to its cultivated acreage and that factor was certain to bring purchasers of agricultural machinery. But, Sir Walter continued, problems of mechanisation ought not to be treated in isolation. There was, he thought, too often a tendency to-day to look for a magic formula which would increase production. There were enthusiasms for such things as work study, incentive schemes and joint consultation, all of them subjects requiring careful examination, but which could only be successful if they were part of a general management plan. Possibly the most important element in the art of management was to get a balanced appreciation of all the things which made for greater efficiency and to ensure that advance was made on a broad front. We were living in the age of experts, Sir Walter said, and sometimes it must be peculiarly difficult in industry to get a composite picture of all the essentials, but that, nevertheless, must be the responsibility of top management.

Lancaster-Morecambe-Heysham Conversion to 50c/s Single Phase

Conversion of the Lancaster–Morecambe–Heysham Line to 50 c/s, single-phase working was completed at the end of last year. Since then trials have been carried out to test the electrical equipment and assess the effects of this method of electrification on the power supply, telecommunications and signalling systems. Full electric operation of the passenger train services was resumed on August 17th. The following description of the new system is derived from a recent visit.

LAST week, at the invitation of British Railways, we were able to see something of the conversion to 50 c/s, single-phase working on the Lancaster–Morecambe–Heysham line. Our visit began at Lancaster Castle Station, where the party boarded a special train to Green Ayre substation and then proceeded to Morecambe, after alighting to inspect the 4000ft section of experimental overhead equipment.

Before referring to the new system it may be as well to recall, briefly, the history of the conversion. The line (Fig. 1), which is about 9 route miles in length, was originally electrified by the former Midland Railway on an experimental basis to assess the merits, for electric traction in

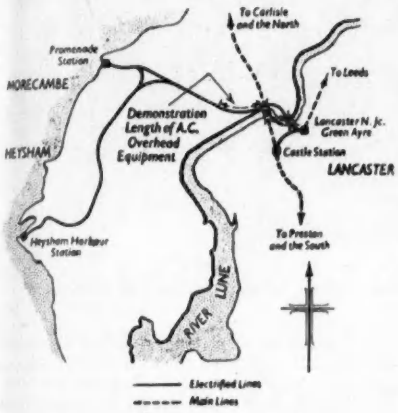


Fig. 1—Lancaster - Morecambe - Heysham Electrification

this country, of alternating current supplied at 25 c/s, 6·6kV, to an overhead contact wire. In 1951, the original trains had to be withdrawn from service because of their age. However, the overhead equipment was in reasonably good condition and it was suitable for use at a higher frequency.

In the meantime, a close study had been made of the important development work done by the French National Railways on the use of single-phase power at 50 c/s on the contact wire. A good opportunity to acquire first-hand experience of the new system presented itself on the Lancaster–Morecambe–Heysham line, where, as already stated, the trains required replacement, while the overhead equipment was suitable for conversion.

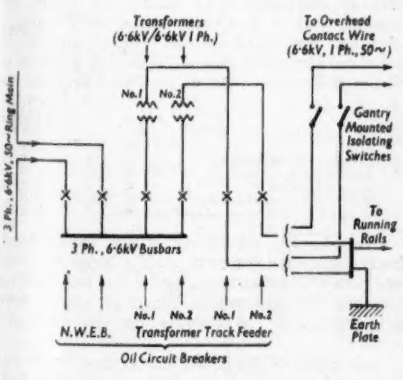
To avoid delay full use was made of existing equipment. At the expense of some loss of seating accommodation the electrical apparatus was installed in old-fashioned rolling stock in a compartment above the underframe as described below. In any future full-scale electrification, however, all the power equipment would be mounted below the floor.

At present three trains converted in this way give a half-hourly service.

Power Supply and Substation

Power for the line is taken from the North-Western Electricity Board's 6·6kV, three-phase ring main into a single substation which was built at Green Ayre Station, Lancaster, to replace the old 25 c/s motor generator frequency conversion plant at Heysham Harbour substation. The new building is a precast concrete structure, of standard L.M. Region design. The substation equipment (Figs. 2 and 10), supplied by the English Electric Company, Ltd., consists of two incoming oil circuit breakers, two transformer oil circuit breakers, two 6·6kV/6·6kV, type "ON" 833kVA single-phase outdoor transformers, and two track-feeder oil circuit breakers (Fig. 10). The transformers may be operated in parallel, but will normally be used singly, one serving as a standby for the other. The track feeders have instantaneous over-current protection, and the other circuit breakers have normal protection. Both transformer and track-feeder circuit breakers are arranged for remote control from an operating panel in Green Ayre Station signalbox, some 50 yards from the substation.

Both tracks are fed from one phase to avoid the expense of sectioning the original overhead equipments. However, the results of tests made with the North-Western Electricity Board show that on a scheme of this size no difficulty is experienced on the supply network through unbalanced loading.



Transformers are connected across red and blue phases at substation busbars.
Centre poles of transformer and track feeder O.C.Bs are not used.
Contact wires of up and down electrified lines are connected solidly together throughout the system.

Fig. 2—H.T. Connections at Green Ayre Substation

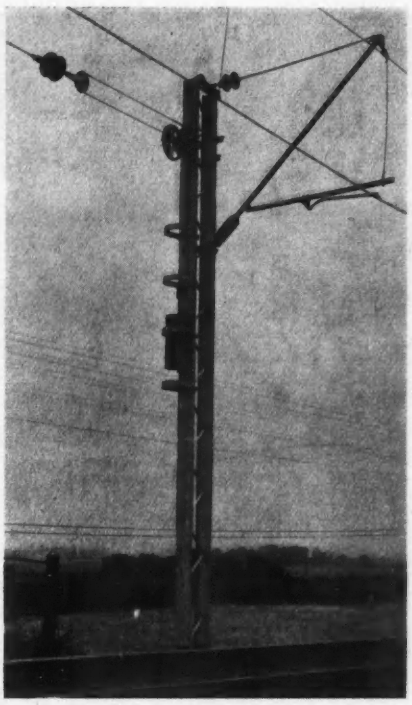


Fig. 4—Balance Weight Termination on Self-Supporting Pole

Overhead Equipment

A length of approximately 4000ft of the original two-track, wood-pole and steel bridge, portal construction between Green Ayre and Morecambe (Promenade) stations was removed and replaced by the British Insulated Callender's Cables, Ltd., by up-to-date light, single-track, hinged cantilever construction.

The new equipment is designed for 20kV, since it is probable that a.c. electrification would

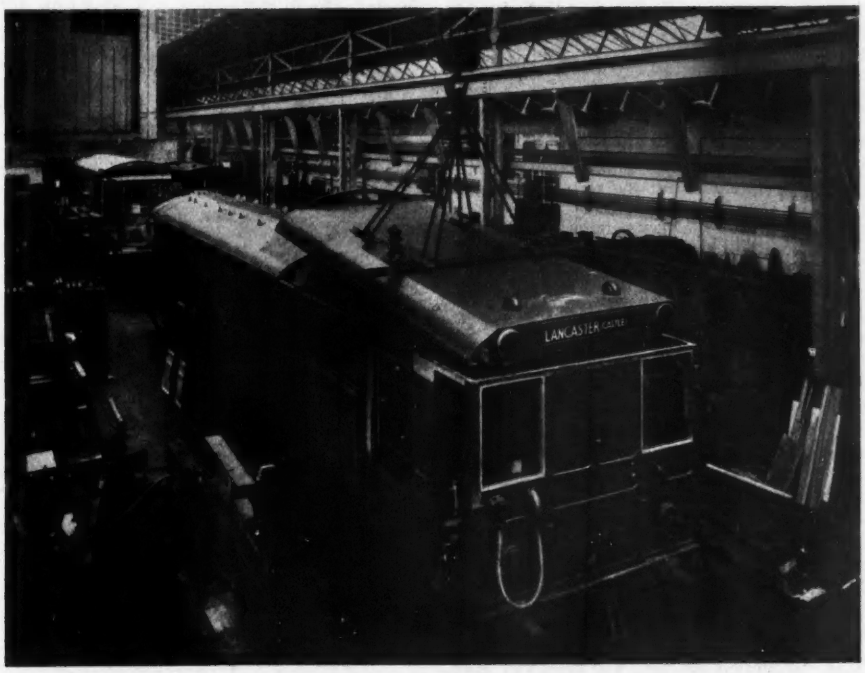


Fig. 3—Rolling Stock with Removable Roof Over Equipment Compartment

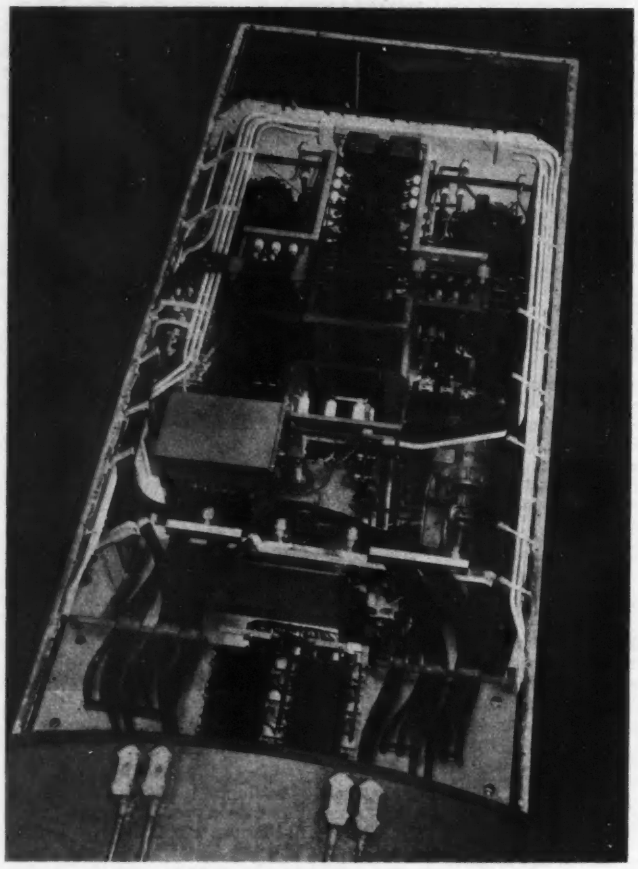


Fig. 5—Equipment Compartment with Roof Removed

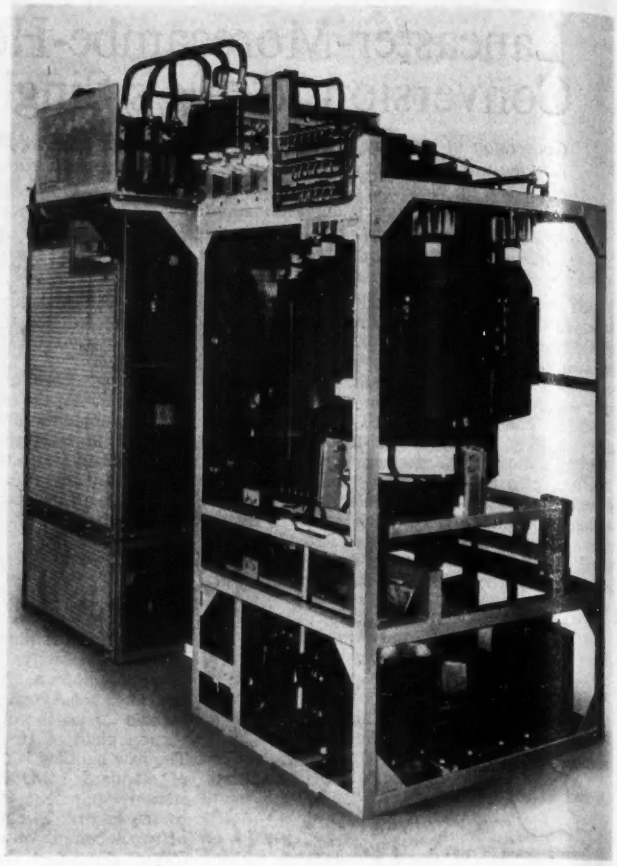


Fig. 6—Rectifier Cubicles before Installation in Coach

generally be carried out at a higher voltage than the 6·6kV which was used for the original electrification and is retained for convenience. A simple catenary construction is employed, using a 7/·116in stranded hard drawn copper catenary and a single 0·166 square inch cadmium copper contact wire, which is suspended from the catenary by $\frac{3}{16}$in diameter semi-hard drawn copper dropper wire. Automatic tensioning by means of balance weights has been adopted and the system as applied to a self-supporting lattice steel pole is illustrated in Fig. 4. The site chosen includes both curved and tangent track.

On the down line an overlap span has been installed in the centre of the length on the curved section of the track, thus dividing the equipment into two individually weight-tensioned parts. The balance weights are installed at the overlap span. At the remote ends where it overlaps with the old fixed equipment the new equipment is fixed.

On the up line the new equipment is anchored at the centre of the length by staying the mid-point cantilever back to the masts of the adjacent structures on either side, and the balance weights are installed at the remote ends where the new equipment overlaps with the old.

The contact wire is positively registered at each supporting point. On tangent track the catenary is retained over the centre line of the track, while the contact wire is offset on either side of the centre line at alternate supports. On curved track the contact wire is offset towards the outside of the curve and is tangential to the centre line of the track at mid-span.

Because the line is near the coast and is subject to the effects of steam traffic, the conditions are suitable for comparative tests of the corrosion-resistant properties of several kinds of masts and protective treatments. Seven different kinds of supporting masts have been installed—rolled steel joists, steel broad flange beams, aluminium alloy broad flange beams, lattice steel, tubular steel, prestressed concrete, and creosoted wood. Some of these supports were described and illustrated on pages 95 and 96 of our issue of January 16, 1953. The methods used to protect the masts against corrosion include galvanising, flame cleaning and painting, pickling and painting, shot blasting and metal spraying—in all, a dozen different varieties of protection have been used.

Some of the hinged cantilevers are fabricated from steel angles and tees, others from steel tubes, and others from aluminium alloy sections. Pin, cap and pin, and solid-core insulators are incorporated in various cantilever arrangements. From the experience gained with this experimental section the company has made considerable progress towards standardisation on a number of items, including dropper wires, and hinged steel tube cantilever supports in which no torque is imposed on the supporting pole by the catenary or contact wires.

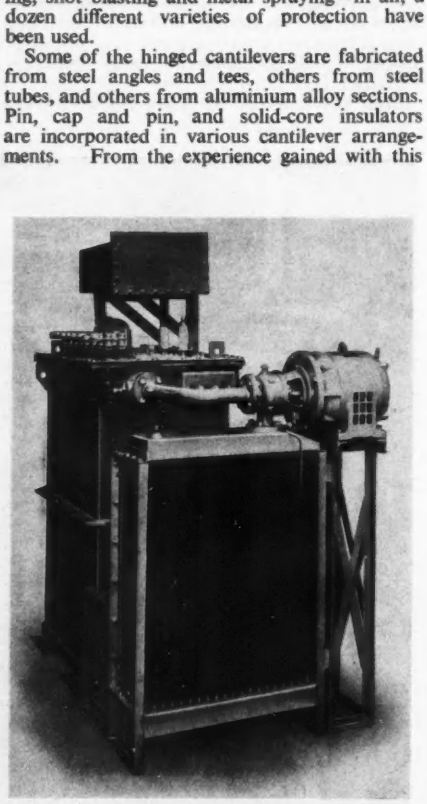


Fig. 7—Rectifier Transformer and Oil Cooling Assembly

Rolling Stock

To provide rolling stock in place of the original train sets, use has been made of three of the three-coach (MC–T–DT) electric train sets made surplus by the closing to passenger traffic in 1940 of the Willesden–Earls Court Line. These train sets were built by the Metropolitan Carriage, Wagon and Finance Company in 1914 and were originally fitted with Siemens electrical equipment. Conversion of the train sets was carried out at the Wolverton Carriage and Wagon Works of the London Midland Region.

Each train set consists of motor coach, trailer coach, and driving trailer coach, equipped to give an acceleration of about 1·3 m.p.h. per second, and a maximum speed of 75 m.p.h., although the speed on this section will not, in practice, exceed 60 m.p.h. The main dimensions of the rolling stock are as tabulated herewith :

	Motor coach Ft	in	Trailer and driving trailer coaches Ft	in
Length over headstocks	57	0	57	0
Bogie centres	37	6	38	0
Bogie wheelbase	8	9	9	0
Width over body at waist ...	9	0	9	0
Height from rail to top of roof	12	0	12	0

Considerable rebuilding of the motor coach body was called for to provide a larger electrical equipment compartment, and a flat well roof for housing the pantograph, the stock having been originally built to operate on the third rail system.

The length of the equipment compartment was increased from 8ft 4in to 15ft and the steel body framing pillars so disposed as to accommodate the motor-operated dampers for air circulation. The steel-framed well roof extending over the driving and equipment compartments was built as a complete removable unit, to facilitate erection and renewal of electrical gear (Fig. 3).

Steel is used for the floor plate of the equipment compartment and for the partition between the driving and equipment compartments. The partition between the equipment compartment and the guard's compartment is of timber, lined with asbestos on the equipment compartment side. At the top of this partition is fitted a shallow window giving a view of the well roof and enabling the pantograph to be observed in service. Separate compartments were provided for the guard and for luggage, the luggage compartment being fitted with double doors. These modifications resulted in a reduced length of passenger compartment and consequent loss of seating. All the original seates were removed and replaced with transverse, tubular framed, coach type double seats, the changes in seating capacity being tabulated herewith :

	Original seating	Revised seating
Motor-car	40	28
Trailer car	66	62
Driving trailer car	60	56
Total	166	146

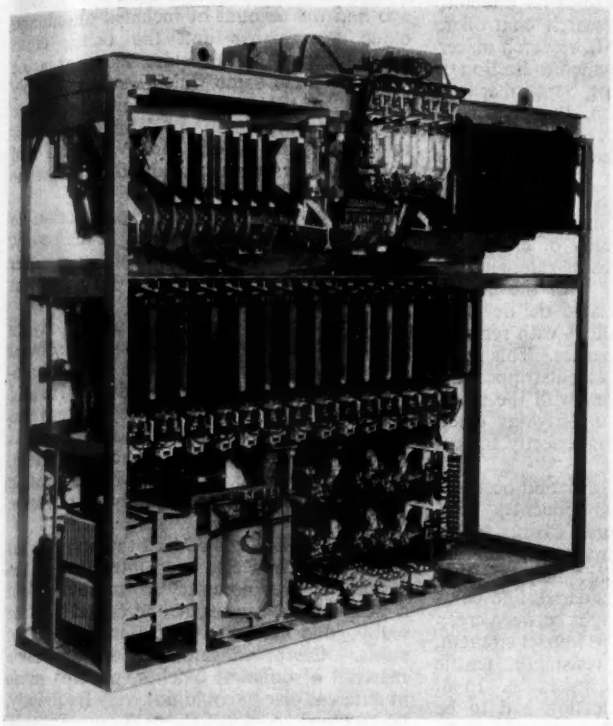


Fig. 8—Main Equipment Frame

No structural alterations were made to the passenger compartments of any of the cars, but the interior finishing was renovated and lightened in colour.

All underframes were overhauled, the existing conduit being removed and step boards and brackets modified to suit the British Railway loading gauge. The disposition of equipment on the motor-car underframe was entirely rearranged and necessitated the fitting of numerous trimmers for mounting the various details. The original Westinghouse brake was retained, but the hand-brake column and associated gear, originally fitted in the guard's compartment, was removed, the handbrake in the driver's compartment being retained.

Because train line connection boxes were fitted on the ends of each car, it was found necessary to increase the buffer projections slightly at the close coupled ends, and to make a corresponding increase in drawbar connections, to give the requisite clearance on curves. All bogies were overhauled and slight modifications made to the motor bogie transoms and swing beams, to allow for the beam type motor nose suspension adopted for this experimental stock.

Electrical Equipment

The electrical equipment of the three three-coach train sets was supplied and erected (Fig. 5) for experimental purposes by the English Electric Company, Ltd., using components which were readily available. It is not representative of future equipment which would be under-frame mounted to avoid loss of seating capacity.

Power at 6·6kV, 50 c/s, is collected from the overhead contact wire by a single pantograph and fed, through high-voltage fuses, to the equipment compartment which contains the bulk of the power equipment, including transformer, rectifiers, control equipment, and part of the associated auxiliaries. Under the coach are mounted the electro-pneumatic motor reverser, notching and field divert resistances, the motor-driven compressor and the 24V battery for emergency lighting of the equipment compartment.

Power is fed to series-wound d.c. traction motors via a transformer and rectifiers (Fig. 9). The transformer has a double secondary winding, each half of the winding being provided with tappings. There are two rectifiers (Fig. 6), each with six anodes which are paralleled in groups of three. Each rectifier is a sealed steel-tank, air-cooled mercury-arc unit, fitted with heaters to ensure correct operation when starting up from cold. Each rectifier feeds two traction motors connected in series with the mid-point earthed.

The transformer contains a tertiary winding, 230–0–230V, for auxiliary services. Train lighting is supplied through separate step-down transformers at 24V working off the 230V supply. Train heating is obtained from the tertiary winding at 460V. The compressor used in connection with the air brakes is driven by a standard d.c. motor supplied through a dry-plate rectifier with smoothing circuit. The remaining motors are capacitor motors supplied from the tertiary winding.

The motor coach is driven by four axle-suspended, self-ventilated traction motors, which are d.c. series-wound machines, each of 215 h.p. at the one-hour rating. This rating was chosen to give an equipment capable of high acceleration

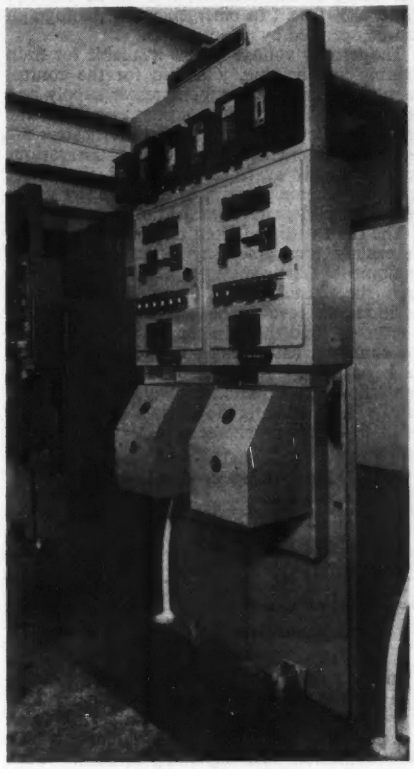


Fig. 10—Interior of Green Ayre Substation

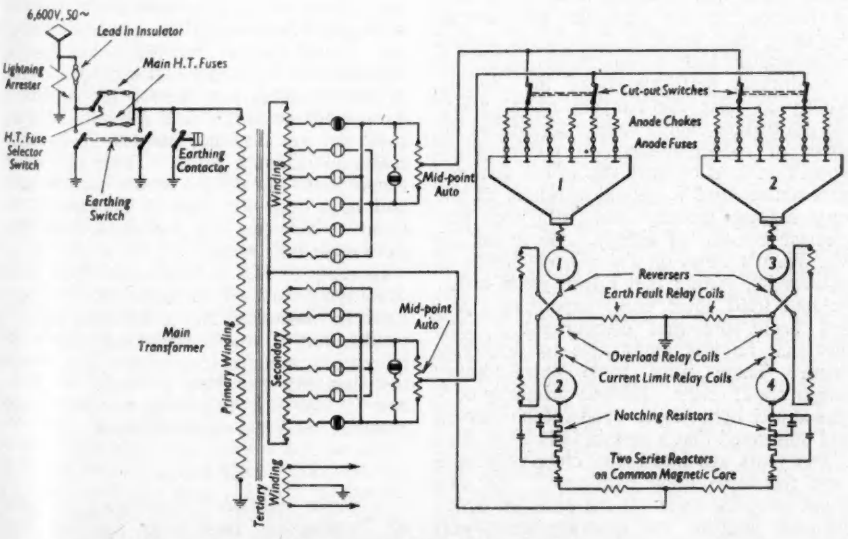


Fig. 9—Basic Diagram of Motor Coach Power Circuits

for experimental purposes. Control of the traction motors is obtained by varying the transformer secondary voltage by an " on load " tap-changer, consisting of two sets of cam-operated contactors and auto-transformers with mid-point tappings. The equipments are designed so that the train sets can be operated in multiple.

There is a high-tension fuse between the pantograph and the primary of the power transformer in the high-tension compartment, and a lightning arrester is provided on the roof. Overload protection is provided by over-current relays and contactors in the d.c. circuits, while six anode fuses are provided for each rectifier. Some smoothing of the d.c. ripple is obtained by the use of a d.c. reactor consisting of two series reactors on a common magnetic core.

The power transformer (Fig. 7) is oil cooled, and the cooling circuit includes a radiator with its motor-operated fan. The equipment compartment is fitted with electrically-operated shutters under the control of thermostats so as to control the incoming and outgoing air flow of

the compartment. Thus, the temperature of the air used for cooling the rectifiers is automatically controlled.

The layout of the electrical equipment can be seen in Fig. 5. In the front of the equipment compartment, immediately behind the driver's cab, are the main rectifiers—one on each side of a central gangway. Above this gangway is a gantry supporting the four rectifier anode chokes and two rectifier-fan-motor condensers. Mounted centrally behind the rectifiers is the main transformer. On the left of the transformer is a gangway which gives access to the main equipment frame, which is mounted on the rear wall of the equipment compartment.

The accompanying view of the equipment frame ready for installation shows the cam-operated tap-change switches, electro-pneumatic contactors and control auxiliaries (Fig. 8).

Operation

The driver's cab contains a master controller, air brake valve, driver's control and indication panel, and a cupboard for the fuses, contactors, &c., which are used in the auxiliary and control circuits.

By depressing a push button the pantograph is raised by residual air pressure in the pantograph reservoir, and contact with the overhead line energises the rectifier transformer through the 6·6kV fuse. In emergency the pantograph can be operated by a foot pump.

The tertiary voltage is now available for train lighting and heating, and also for the control supply, battery charger, compressor supply and auxiliaries. The compressor starts up under the control of its governor and rectifier heaters are energised automatically. Provided the various control supply switches are closed the driver waits for the air pressure to build up, by which time the rectifiers have warmed up.

The train is driven from the master controller in exactly the same way as a standard d.c. equipment. The removable key is first inserted, then the master switch thrown to the "on" position, the reverser handle to "forward" or "reverse" and then the main power handle to the shunting, half-voltage, full-voltage, or weak field position. Acceleration is automatically controlled by a current limit relay up to whichever of the four running notches is chosen. The main performance characteristics are tabulated herewith :

Main Performance Characteristics

Line voltage (at no load)	6,600V
Line frequency	50 c/s
One hour rated output at wheels (allowing 10 per cent line drop)	860 h.p.
One hour rated tractive effort (in full field)	11,500 lb
Average accelerating tractive effort	17,900 lb
Wheel diameter (mean)	42in
Gear ratio	65/16
Maximum permissible speed for equipments	75 m.p.h.

Signalling and Telecommunication Equipment

In changing from the previous 25-cycle installation to the 50-cycle system, the higher load current and frequency and the rectifier ripple on the trains greatly increased interference to telecommunication and signalling circuits. Tests confirmed the need to replace the overhead communications route by means of buried cable. Two separate cables are provided for telecommunications and signalling circuits respectively. Both are lead-covered, double steel tape armoured and served. The conductors of the fourteen-pair star quad air-spaced cable employed for the telecommunication circuits are 40 lb per mile and are provided with a double-tape copper screen below the lead sheath. In the signalling cable the conductors are 1/·064in diameter with oil-impregnated paper insulation, the size of cable varying along the route between twelve and forty-eight conductors.

The change of frequency and increased load affected the existing track circuits. There were some thirty d.c. single-rail track circuits working reasonably well when the maximum return traction current was low, but the increased return current of the new scheme necessitated alteration of the relays and of the feed end arrangements. The stray alternating currents in the track circuits have been limited by the insertion of a choke in the feed end, and the relays have been altered internally by providing a magnetic shunt and copper slugging so that alternating current would not energise them.

The British Association

No. IV—(*Concluded from page 392, September 25th.*)

The Design of Creep-Resisting Steels

A PAPER entitled "The Design of Creep-Resisting Steels," by Mr. E. W. Colbeck, F.I.M., metallurgical and research director, Dr. J. R. Rait, F.I.M., research controller, and Mr. J. O. Ward, A.I.M., research officer of Hadfields Ltd., was presented to Section G of the British Association on September 8th.

Professor W. J. Kearton, the chairman, said that it was the first occasion on which a metallurgical paper had been given to the British Association.

The paper was presented by Mr. J. O. Ward. It was remarked in the paper that from 1930 onwards the study of creep had proceeded at an ever increasing rate, and the demands of war, together with the advent of the gas turbine, necessitated the development of steels and other alloys with remarkable high-temperature properties. This rapid technological expansion had outstripped the development of creep theory with the result that the mechanisms underlying creep deformation were as yet imperfectly understood.

This time dependent deformation occurred in many engineering components, such as turbine blading, rotors, cases, superheater tubes, furnace components, &c. In most practical applications, factors other than creep had to be considered, and compromises must often be sought between creep resistance and such factors as impact strength, corrosion and oxidation resistance, tensile strength and thermal shock resistance. In all cases the method of fabrication had to be considered and it should be pointed out, in this respect, that creep resistance usually implied metallurgical characteristics which caused difficulty in forging, heat-treatment and machining.

No one material could be supplied which would meet all these requirements, and the relative merits of materials were difficult to evaluate except for a specific application. For example, a material treated to give the maximum creep resistance for turbine-rotor purposes would not necessarily be suitable for extrusion applications because the normal hot tensile strength would be too low.

Major P. L. Teed said that Mr. Ward had disclosed an immense amount of work which was of tremendous importance in relation to the airborne gas turbine. Anything which could be done to reduce fuel consumption had a tremendous effect on the ultimate performance of the aircraft. Ability to raise the temperature at which the gas turbine engine could operate had the effect of reducing the fuel consumption. Thus, that kind of work was of real national importance, and it should continue at the very highest priority and with the very greatest amount of energy. He asked for Mr. Ward's views on the reproducibility of test results, stating that fifteen years earlier he had tried some creep experiments and had been somewhat discouraged by the fact that he was never able to reproduce them. There were some extraordinary things about creep. He was primarily concerned with light alloys. It had been observed and confirmed that a certain light alloy used fifteen years ago had better creep resistance than the same alloy had now. The two alloys were the same on the basis on which chemical analysis was generally done, and the microstructure was substantially the same, but there was a great difference in creep resistance. The accepted explanation was that the melting of light alloys was carried out with less technique fifteen years ago and the amount of included aluminium oxide was higher and the better creep characteristics of the older material arose because of the oxide which was presumably located in the grain boundaries. In the old alloys a large grain was definitely superior to a fine grain. What Mr. Ward had said about the ferrites seemed to indicate that the reverse would be the case.

Mr. Ward said that a reproduction to ±5 per cent was considered satisfactory. In the case of an experiment by another laboratory, a reproduction to ±10 per cent was considered satisfactory.

He added that the point about oxygen in aluminium was interesting, and he showed a slide giving the creep curve of pure aluminium across the grain boundary. He said it had been shown that the steep pattern was where the whole boundary moved from its original position into an adjacent position. There was a quiescent period when migration occurred, which was probably a diffusion process.

Mr. G. L. Bailey said that the non-ferrous metal world had also been interested in the structure it was necessary to improve to get a creep-resisting material, and added that the really good creep-resisting metals were not steels. Creep measurement on the same material of different batches, perhaps made in different places, could not, very frequently, be repeated to closer than 20 per cent. In the case of the results given in the paper of the measurement of total plastic strain after 1000 hours in relation to the effect of the vanadium-carbon ratio of the steel with two different heat treatments, it was said that it had no effect at all because the differences in the normalised material which had not been tempered were not significant. Admittedly, if one normalised and tempered a low vanadium-carbon ratio material it seemed to have some claim to be creeping a little more than others, but what importance did Mr. Ward attach to differences of that order ?

Mr. Ward said that there was considerable scatter in the results and so far not enough was known about interference effects. The work which was being done was beginning to show how the alloys behaved, but so far one variable at a time only had been dealt with. When chromium was present, the vanadium did not behave as it should do. All that they could say was that they had seen it, but they could not account for it. There was much to be done, but on the whole enough tests had been done for them to be sure of the trends ; but they did not claim that they were more than trends.

In reply to Mr. J. S. Forrest, Mr. Ward said that statistical methods had not been used in assessing the significance of the results, but it was a technique which the laboratory intended to employ. The laboratory had been working for only ten years, and it was just beginning to get enough material to do real statistical work.

Titanium

A paper entitled "Titanium : a Metal of Engineering Importance ?" was then given by Major P. L. Teed, F.R.Ae.S.,

deputy chief of research, aircraft, Vickers-Armstrongs, Ltd. In presenting his paper, Major Teed said that its title posed a "64-dollar" question. The answer depended on what was meant by "engineering importance." The engineering importance of a metal depended on its possession of one or more chemical or physical qualities, which determined whether engineers required it, and its cost, which determined whether they could afford it. He contended that even at present prices titanium and its alloys could be economically employed, and thus the metal was of economic importance. Titanium had a definite, although at present very limited, field of application in aviation. In the paper the author summed up the engineering qualities of titanium and its alloys in the following sentences.

(1) Titanium and its alloys, compared with most other engineering materials, are extremely costly.

(2) The mechanical properties of commercially pure titanium are comparable with those of mild steel, except as regards its Young's Modulus. This is about half that of ferritic materials and one and a half times that of an aluminium and its alloys.

(3) The mechanical properties of titanium alloys, excluding their Young's Moduli (15 to 18×10 lb^6 per square inch), are at room temperature, comparable with those of most alloy steels.

(4) The specific gravities of the titanium alloys being about 4·3 to 4·7, their room temperature specific mechanical properties, other than elastic moduli, are very high.

(5) Titanium alloys, like those of other metals, are heat sensitive. Above 100 deg. Cent. they have better specific mechanical properties than the wrought aluminium ones under comparable conditions, but at temperatures in excess of 400 deg. Cent. those of several ferrous and non-ferrous alloys are superior to the best of the titanium alloys. Above 800 deg. Cent. nitrogen, oxygen, steam, carbon monoxide, carbon dioxide, react somewhat vigorously with the hot metal.

(6) Titanium and its alloys have high melting points as compared with alloy steels.

(7) The workability of titanium and its alloys presents considerable difficulties. Castings for most purposes cannot be made. Forging is more costly than that of alloy steels. Welding calls for special techniques. Machining is somewhat more difficult than that of austenitic steel. Cold reduction necessitates new or modified methods.

(8) Titanium and its alloys are resistant to many forms of chemical attack. In particular they have a singularly good resistance to sea-water, even when this is hot.

(9) The rubbing properties of titanium and its alloys are poor. They possess a marked tendency to pick up on themselves and on other metals.

In reply to Professor H. O'Neill, who asked why titanium welded so easily, Major Teed said that he did not know why the metal picked up as it did. Methods for the prevention of the picking up had not been really successful, but the best way was to use a titanium bolt with a copper-nickel alloy nut, although something was sacrificed by having to use the dense material for a nut.

Mr. G. L. Bailey said that Major Teed had expressed a much more optimistic view about the possible uses, even at present prices, of titanium than on the last occasion on which he had heard him speak, and he wondered why that was. He was interested in the possible use of titanium in other directions than the aircraft industry, where costs of construction were much lower. The corrosion resistance properties of titanium were fantastically good in some respects. The sea-water corrosion resistance was amazing, and one would dearly like to see titanium usable for such things as condenser construction in naval vessels. He wished a naval architect would do similar work on the use of titanium for cooling water systems in H.M. ships.

Major Teed said that on the last occasion when Mr. Bailey heard him speak he was addressing aeronautical engineers about the application of the metal to airframes. By carrying his analysis into the engine he had entered a much more rewarding field. It seemed to him that the possibilities of the titanium tube for naval condensers ought to be explored. Perhaps Wing-Commander Cave-Browne-Cave would tell them some of the variables. He imagined that a tube which would allow a water passage of 40ft per second would permit a condenser to be made much smaller in volume. He believed that in the case of certain classes of naval vessels that would be regarded as very rewarding.

Wing-Commander T. R. Cave-Browne-Cave, said that Major Teed's suggestion for the application of titanium to condenser construction was a very appropriate one. He believed that if one had a metal which was as resistant to sea-water corrosion as titanium was, one would then change the type of condenser radically. If one had a material which in "thin" thicknesses was really proof against corrosion, such as gold, he believed that the condenser would not be like it was at present, but would resemble more the type of heat exchanger used for the radiator part of an aircraft where the metal surfaces were of paper thickness and the resistance to flow through the ducts was very much less than it was in an ordinary tubular condenser. In experimental work at Southampton a steam condenser had been made rather on those lines, disregarding for the time being the properties of corrosion, and there had been obtained rates of condensation per unit block volume of the condenser three times greater—not 3 per cent more—than with the conventional Admiralty construction. The Admiralty, rightly, was a little doubtful about using thin alloys in any form in which they would be liable to serious failure by sea-water corrosion. However, except for the fact of corrosion, there was no doubt that the size of condensers could be reduced enormously. It was possible that Major Teed's titanium alloys might very soon make that kind of development practicable. For that purpose, a strip which could be welded by a gas brazing process or something analogous was required. In the early days after the introduction of both aluminium and magnesium the price per pound of the materials and their alloys was enormous. On similar considerations, was the price of titanium and its alloys likely to fall very greatly as their use became wider ?

Major Teed said he was glad Wing-Commander Cave-Browne-Cave had borne out so clearly his own feelings about the application to the naval steam condenser. He believed that the price of titanium would come down. American firms had said that there could be no reduction in price for the next three years, but the sole British producer had said that a halving of the price was possible in three to five years. Anything produced by a batch process, as was titanium, was expensive because of the man-hours lost in closing down the process and preparing for the next batch, and because of the loss of residual heat, and so on. In America a method was being used which was claimed to be a continuous process and would certainly run for very much longer periods. In spite of the propaganda against a reduction in the price, he considered that it would come about.

Professor W. J. Kearton, the chairman, said that attempts had been made to generate power with increased thermodynamic efficiency by the use of a combination of mercury and steam. Practical difficulties with the process had been confined to the mercury boiler, mainly because it was difficult to transfer heat from the steel tube containing the mercury to the mercury itself, in that mercury did not wet steel as water did. Also, in the temperatures required in the mercury boiler, in time, steel was dissolved by the liquid mercury. The problem had been overcome by the addition of powdered titanium which formed a titanium-steel alloy. This overcame the difficulty of the dissolving of the steel and enabled the mercury to wet the steel tube, and that permitted the use of far greater rates of heat transmission. There was no doubt that the problem of the boiler had been solved by the use of the metal.

The Isodynamometer

On Tuesday, September 8th, the first paper presented before Section G (B) was entitled "The Isodynamometer," by Mr. J. Wright, assistant civil engineer, Merz and McLellan. In opening his paper, Mr. Wright remarked that owing to its ready workability under office conditions, celluloid was often used for constructing models for the analysis linear plane frames. This material obeyed Hooke's Law satisfactorily over a sufficiently wide range of stress, and while it exhibited creep under constant load, the nature of the creep appeared to be such that the total deflection at any instant was directly proportional to the magnitude of the load, and means of compensation were possible. T. M. Charlton had recently proposed a creep-compensating technique for use with celluloid models to obtain the forces and moments in the members of the respective prototypes. It was known as the "isodynamometer" technique although originally the instrument was called a "dynamometer." The author had carried out some tests on a celluloid model of a simple portal frame, using an isodynamometer of his own design and construction, and details of these tests, with an explanation of the theory of the technique and the accuracy of the results obtained were given in the paper.

The results of the tests described in the paper showed that the isodynamometer technique was a promising addition to the model analysis methods which were already available to the structural engineer. The results compared well with the calculated values, the greatest discrepancy being 4·1 per cent, but generally were less than 1 per cent.

Combined Magnetisation

A paper on "Combined Magnetisation of Magnetic Materials" was next presented by Mr. J. E. Parton and Mr. W. D. Sutherland, Lecturers in Electrical Engineering, Glasgow University. The main points in the paper were :—

The variation in the iron loss which occurs in magnetic circuits under conditions of single-frequency magnetisation is well known and several formulæ (mostly empirical) are available to compute these losses for various values of magnetising force and flux density. To obtain any degree of accuracy when using these formulæ the magnetisation is usually considered to be taking place under

" sine-flux " or " sine-current " conditions. The former is, of course, the standard test method, because when a sine voltage is applied to a winding on a magnetic material, the resulting core flux will be sinusoidal if the winding, as is usual, has negligible resistance and leakage reactance. The sine-current test may sometimes be used, but the difficulty of obtaining " sine current " sources usually restricts its application to special cases.

In most electrical machinery and transformers the applied voltages are so nearly sinusoidal that the cores are magnetised under conditions of sine-flux, and an estimate of the resulting iron losses can be readily made. There is, however, a number of conditions where the iron circuit is subjected to simultaneous magnetisation from two sources, the frequencies of which may or may not be integrally related. For instance, the variation in the permeance of the magnetic circuit in an alternator due to the effect of the teeth causes high-frequency flux components to be superimposed on the fundamental-frequency flux density in parts of the iron circuit. These " tooth ripples " cause changes in the core loss. A further example of combined magnetisation occurs in the familiar smoothing choke employed in rectifier circuits. In this, the iron circuit is subjected to a magnetising force wave containing the polarising component h_o and alternating components at frequencies of $2f$, $4f$, &c., if used in a full-wave rectifier circuit, or f, $2f$, $4f$, &c., for the half-wave case, f being the fundamental frequency. It is obvious that prediction of the resulting iron loss in the magnetic material under the above conditions cannot be done from previous single-frequency results. The paper considers in detail the nature of some of these multi-frequency magnetisation conditions and investigates the resulting iron losses.

Calorimetry

A paper on " Applications of Calorimetry with reference to Magnetic Steels " was then presented by Mr. K. L. Morphew, Lecturer in Electrical Engineering, Southampton University. The following paragraphs are reproduced from it:—

An aspect of electrical measurement in which calorimetry has not been extensively used, is that of magnetic iron-loss testing. Usually, loss measurement is made with a wattmeter, or an alternating current bridge or potentiometer (according to the degree of precision required), while the frequency of magnetisation and mean magnetic induction are held constant. In work of this kind care has to be taken to ensure that harmonic distortion is either allowed for, or does not affect the result. The deliberate introduction of harmonics, and the use of feed-back, are two methods by which distortion may be counteracted.

Calorimetry was first introduced into this field by Greig and Kayser in 1948. They used an Owen bridge for iron-loss measurements at high frequency, the balance detector being a harmonic analyser, which also enabled the voltage harmonic components to be measured and used in a correction term. Their calorimeter, for which a repeat accuracy of better than ± 1 per cent was claimed, served to monitor the reliability of the bridge. The calorimetric method used was one in which the alternating magnetisation of an iron specimen produced heat which was shared by all parts of the calorimeter and its fluid surround.

This kind of measurement is akin to work being done at Southampton University on the thermal properties of electrical sheet steels. In particular, the specific heat of these steels is an unknown. A method of measuring it is being developed in which the specimen does not share its heat with a calorimeter and cooling fluid, but acts as its own calorimeter. The temperature change is preferably measured over a very small interval of time so that heat losses by radiation, convection and conduction through the supports to the specimen will involve only a very small correction. As a consequence, the temperature rise will also be small, of the order of 0·1 deg. Cent.

Dynamical Analogies

Lastly, Mr. R. Yorke, of Southampton University, presented a paper on " Dynamical Analogies." He said that the oscillations of a simple pendulum or the vibration of air in a Helmholtz resonator, although occurring in different media, were alike in so far as the equations describing the motion were concerned. A similar kind of oscillation could also occur in electric circuits and again the equations describing them were similar in form. It was, therefore, possible to think of any one of these systems in terms of the others, and in many practical cases it was advantageous to do so.

The principal advantages of doing this were, first, that the mathematical methods developed to deal with complicated electric circuits may be brought to bear on mechanical problems without modification ; secondly, mixed electrical and mechanical dynamic systems may be simplified for the purpose of analysis by using the analogy to reduce the dual system to a single equivalent network, and, thirdly, the equivalent electric network may be set up and used as an analogue computer, which allowed a rapid assessment of the performance of the mechanical system to be made. Further, changes in the electrical parameters may be quickly made and the effects of these changes used to predict the result of similar changes in the original system.

Transmutation

Three papers dealing with transmutation were given to the Chemistry Section (Section B) on Tuesday, September 8th.

Dr. R. Spence, Chief Chemist, A.E.R.E., Harwell, in a paper entitled " Transmutation and Chemistry," said that one of the most important transmutation processes was that which occurred when the isotope 235_U underwent fission in a nuclear reactor. If the construction of nuclear reactors for the generation of electrical power proceeded as was expected, it was likely that at least 1 ton of fission products would be produced in Britain per annum by 1970, while it was possible that total world production would be as much as 100 tons per annum by the end of the century. The long-term future of atomic energy as at present conceived depended on the successful transmutation on an industrial scale of natural thorium into the fissionable isotope 233_U and of natural uranium into plutonium. That would probably be carried out in special nuclear reactors known as converters or breeders.

A wide range of uses for fission product radiation was now being explored ; for example, for the preservation of meat and other foods, for sterlisation of pharmaceuticals, for production and treatment of plastics and for bringing about chemical reactions. The inert isotopes left after total decay of the fission products had isotopic ratios which were completely different from those of the natural elements. Although there was no obvious use for such material at present, it was possible that one would appear before long. As it was conceivable that 1000 tons might have been produced in the world altogether by the end of the century, the quantity would be by no means negligible.

Dr. K. F. Chackett, I.C.I. Research Fellow, Department of Physics, Birmingham University, in a paper entitled " Transmutation by Means of Particle Accelerators," said that the Birmingham University 60in cyclotron had, in common with others elsewhere, recently been used in novel ways by accelerating heavier particles than such machines were originally designed for. The particles were highly ionised atoms such as $^{12}C^{6+}$, $^{13}C^{6+}$, $^{14}N^{6+}$, $^{15}N^{6+}$ and $^{16}O^{6+}$. Those ions had been accelerated into the 100MeV region and could cause reactions in aluminium giving at least twelve different radio-active species. It had been known since 1951 that $^{12}C^{6+}$ ions could be used in bombarding uranium to yield isotopes of the heaviest known element, californium, element 98. The purpose of the present experiments was to see whether the use of still heavier bombarding particles on uranium and plutonium targets would produce more new elements beyond californium.

Present-day researches in nuclear physics were, however, largely concerned with obtaining particles of higher energy than could be achieved in cyclotrons. The reactions induced by protons, deuterons and alpha particles of several hundred MeV given by the 184in synchro-cyclotron at Berkeley had been studied by radio-chemical means. Even higher energies were available from synchrotrons, as opposed to synchro-cyclotrons. The Birmingham proton synchrotron which had recently been put into operation gave protons up to 1000MeV. The main interest in such extremely high energy particles was in the production of mesons, but there could be no doubt that such studies, by extending knowledge of nuclear structure, would ultimately have significant repercussions in radio-chemistry.

Dr. R. Hurst, A.E.R.E., Harwell, in a paper entitled " Synthetic Elements Produced by Nuclear Reactors," said that a tremendous industry had grown up in a single decade to process the products of pile transmutation reactions calling forth the most brilliant efforts of chemical engineers, chemists and metallurgists, to develop new materials and new techniques for remote-controlled chemical processes. Although the importance of that industry had so far been military as providing the explosive for atomic weapons, it was clear that in future the economic importance would begin to take precedence as nuclear power plants began to supplement conventional power supplies. If, in another decade, a large fraction of our power was produced in that way, there would become available hundreds of grammes of neptunium and americium, and grammes of curium, and it was interesting to speculate whether they were likely to have any practical uses. In addition to the formation of the transuranic elements, there also went on simultaneously in the atomic pile another kind of transmutation, the fission of the U235 atoms into fission fragments, which included over thirty elements. Only two of them were not known as natural elements, namely, technetium (element 43) and promethium (element 61), and they were now being separated in gramme quantities for chemical study.

There was already an extensive chemical industry in modern alchemy, the transmutation of one element to another. This could be expected to grow rapidly.

The Aerodynamics of Compressor Blade Vibration*

By H. PEARSON†

The paper considers the causes of compressor blade vibration and shows that, in the unstalled region, damping is almost entirely aerodynamic. When wakes are present, the vibration of the blade may be assessed from the aerodynamic excitation and damping. The high stresses arising from "stalled flutter" are due to the absence of any degree of damping and a modest degree of "built-in" damping would reduce them to safe limits. The phenomenon of the rotating stall is also described. Sections dealing with aerodynamic damping in the torsional mode, cascade tests on stalled flutter, the effects of frequency parameter on stalled flutter, and wake effects installed are omitted in this abstract.

FATIGUE failures of both compressor and turbine blades have been fairly common since the inception of the aircraft gas turbine. This in itself would not be surprising, since the aircraft engine has always evolved through the continued running to destruction of its varied components. Experience shows that these particular failures are not related to the direct loading of these parts and also, similar failures have occurred in industrial designs with no necessity to use such small safety factors. The inference is that such blades have been subject to excitation of intensity bearing little direct relation to the normally imposed centrifugal and gas bending loads for which the blades were designed. It has been a common design assumption that, to allow for vibration, a gas bending load so many times the design gas bending load should be allowed, but it appears that this may not be so and that vibrational stresses bearing no relation to this may be set up.

Fatigue failure of impeller vanes was a common enough trouble with centrifugal compressors; with axial compressors, however, the consequences of one blade failure may be a total wreck of the engine. The problem is therefore much more acute. This does not mean that centrifugal impeller failures were not taken seriously; they were to the extent of almost total elimination, but the possibilities of design alteration to the impeller without any great change to aerodynamic performance were much greater than would appear to be the case with axial compressor blading.

It is generally conceded that nearly all blade vibration is of aerodynamic origin, and this paper is a review of the aerodynamic excitation and damping of compressor blades. Many of the remarks will also be found applicable to turbine blades, but the whole approach to the subject has been made from the compressor application and fortunately, the major phenomenon of blade stall appears to be absent from the turbine. It is not the purpose of this paper to deal with the complex problem of the various modes of vibration of blades singly and in total when assembled in discs.

Since axial compressors of higher compression ratio, i.e. greater than, say, 5 : 1, on one shaft have been constructed, the incidence of blade fatigue failures has increased. Since the "off-design" performance of such compressors is necessarily more critical, the front stages tending to operate stalled while the back stages may run choked, the inference has been made that "stalled flutter" must be playing quite a large part in these failures. This appears to be the case, indeed the problem would appear to be to explain why failures are not more frequent and drastic than they are. This paper deals with "stalled flutter" in some detail.

Excitation.—The blades of a compressor may be excited to vibrate by the following methods :—

(*i*) Transmission of mechanical vibrations through the fixings.

(*ii*) Instability of the blade in the air flow, e.g., stalled flutter, classical torsion-flexural flutter, and so on, taking place automatically at the resonant frequency of the blade.

(*iii*) Aerodynamic excitation caused by pulsations of the air, or the blade running through wakes, and so on.

Generally (*i*) and (*iii*) will only be of much importance when the excitation frequency is close to the resonant frequency of the blade. (*ii*) is dangerous because it occurs automatically at the resonant frequency. An exception to (*iii*) might be cited where an extreme pulsation occurs, such as, for example, the surge of the compressor; although not occurring at the resonant frequency, it is capable of doing great damage. However, surge is a phenomenon that it is always the designer's object to avoid, rather than to design for; it is the object of this paper to deal with vibrations occurring during normal operation of the compressor.

Damping.—Where excitation occurs at the resonant frequency the only factor limiting the amplitude is damping. Damping may occur by :

(*a*) Internal damping of the blade material.
(*b*) Mechanical damping of the blade fixings.
(*c*) Aerodynamic damping.

With the materials at present in use, internal damping may be neglected until the strain rises to such a value that the blade will soon fail. Certain constructions have been prepared, however, to make the internal damping high.

Much discussion has taken place among engineers as to the value of various blade root fixings for damping purposes; it seems difficult to believe, however, that the damping of any root fixing can be appreciable compared with aerodynamic damping under normal conditions, except perhaps at low speeds.

Aerodynamic damping, except for flutter, is the largest factor limiting blade amplitude; oddly enough, even where the excitation is itself aerodynamic. Where excitation is mechanical or aerodynamic (i.e. not flutter), aerodynamic damping appears to be the only factor of great importance, except perhaps at low speeds. For flutter there is no aerodynamic damping (except in the sense that the amplitude of the blade movement may grow so high that excitation is automatically reduced) and the only factors limiting amplitude are internal and fixture damping. This is why flutter is so dangerous—the damping factors are so small.

Vibration.—As this paper is primarily concerned with the aerodynamics of blade vibration, it will be necessary for simplicity to restrict discussion to the elementary cases of fundamental flexural and torsional modes. All higher modes tend to be complex modes of both types, difficult either to visualise or to analyse aerodynamically.

A large number of the failures of axial compressor blades appear to have been simple fundamental flexural failures. Torsional failures do not seem to have been much experienced and this paper gives some reasons why this should be so. Accordingly a great part of the paper deals essentially with the fundamental flexural modes only, and it should not be assumed that the remarks always apply to other modes.

AERODYNAMIC DAMPING

Flexural Mode.—It would be possible to make use of all the work already done for wing flutter theory, but this paper has been written for gas turbine engineers rather than wing flutter experts and therefore the theory is presented in perhaps an elementary fashion.

Aerodynamic damping is caused by the fact that the velocity acquired by a blade while vibrating, automatically changes the incidence of the air stream. If the cascade characteristics are such that an increase of incidence causes an increase in the lift force on the blade, damping will take place; if, however, an increase of incidence causes a decrease in lift, then flutter will take place. Aerodynamic damping is thus the opposite of flutter; although it is by no means universally agreed that the foregoing represents a complete account of conditions leading to flutter, it may be reasonably taken, that in the normal unstalled state, when the blade lift increases with incidence, aerodynamic damping occurs.

It is a relatively simple matter to derive a theoretical expression for the aerodynamic damping for a blade in cascade of given lift-incidence characteristics. In Appendix I the following expression for the energy removed by the air stream from a vibrating blade per unit length per second is given :—

$$\pi^2 f^2 \rho V c a^2 \left[\frac{\partial C_F}{\partial \alpha}\cos(\alpha_1-\xi)+\left(V\frac{\partial C_F}{\partial V}+2C_F\right)\sin(\alpha_1-\xi)\right]$$

Generally $\partial C_F/\partial\alpha$ is much more important than $\partial C_F/\partial V$ except near the limiting Mach number. For compressor blades $\alpha_1-\xi$ is small, and so only the first term need be considered. For turbine blades the full formula has to be used. For compressor blades the damping may be taken, for most purposes, as

$$\pi^2 f^2 \rho V c a^2 \frac{\partial C_F}{\partial \alpha}$$

per unit length per second. This aerodynamic damping is the same whether the air flow is steady or pulsating, so that aerodynamic damping and excitation may take place simultaneously.

Some idea of the magnitude of this damping may be obtained from the following example. For a compressor blade tip of chord 2in, and frequency 400 c/s, in an air stream of 600ft per second, vibrating with a tip amplitude of 0·1in, the energy removed per second per inch length would be 12ft-lb. Presumably, therefore, this amount of energy is being fed in from some source to maintain the vibration. Supposing aerodynamic damping did not exist and this energy had to be absorbed, say by internal damping of the blade material, the energy would all then appear as heat. In still air to radiate this amount of heat the blade temperature would have to be nearly 300 deg. Cent.; in the high velocity stream of the compressor the blade would run at a steady temperature of some 10 deg. Cent. above that of the air. It must be clear that internal damping could never dissipate this amount of energy.

As a demonstration of the damping effect of the air flow an experiment was made in which a blade in a cascade was artificially vibrated by a rod operated from a loudspeaker coil. The stress in the blade was measured by means of a strain gauge, and the loudspeaker was adjusted to give a convenient amplitude in still air. The air flow was then turned on and the resulting stress plotted against the Mach number of the incident air flow in Fig. 2. Unfortunately, this test was made on a turbine blade cascade, but the damping coefficients are about of the same order as for a compressor blade. At all angles tested the stresses fall rapidly with increase of air velocity. The relative stress amplitudes cannot be taken as a direct measure of damping, because it would be necessary to know the variation of energy input from the loudspeaker with amplitude. Nor can the variation between different angles be taken as any relative measure of damping, but the general run of the curves shows the large effect of air flow in damping out blade vibrations.

This experiment must be regarded rather in the light of a laboratory demonstration than as a scientific determination of the value of blade damping capacity.

Frequency Parameter.—In deriving the foregoing result it has been assumed that the blade behaviour is independent of frequency, i.e. that the blade will give a certain lift at a certain incidence whatever the frequency of vibration. This will only be true if the time required to set up the necessary change of circulation round the blade is small compared with the time taken to excite the associated change of incidence. A suitable parameter for measuring this effect is

Notation

Aerodynamic :

ρ—Air density (pounds per cubic foot)
V—Air velocity with respect to blade at inlet to blade (feet per second)
v_a—Axial air velocity (feet per second)
u—Blade speed (feet per second)
α—Air angle measured from axial direction
α_1—Air angle relative to moving blade (in steady state)
ξ—Stagger angle
α_c—Incidence limit for stalled flutter
M—Mach number, except in Figs. 5 and 6, where it denotes mass flow
F—Force per unit length on blade at right angles to chord line, except in Fig. 1 (poundals per foot)
F,G—In Fig. 1, functions of λ
C_F—Blade lift coefficient at right angles to chord line $= F/(\frac{1}{2}\rho V^2 c)$ where F is defined as the force on the blade
W—Work done per second in maintaining an oscillation
λ—Frequency parameter $= 2\pi fc/V$
T—Total temperature

Mechanical :

f—Frequency (cycles per second)
p—Angular frequency $= 2\pi f$ (radians per second), except in Figs. 5 and 6, where it denotes static pressure.
c—Blade chord (feet)
a—Amplitude of vibration (feet)
h—Blade height (feet)
ρ_m—Metal density (pounds per cubic foot)
t—Thickness of root section (feet)
E—Young's modulus (pounds per square inch)
K—Radius of gyration of aerofoil section (feet)

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the ratio of the time taken for the air flow to pass through the cascade to the time taken for one complete vibration. In the United Kingdom the accepted definition of the frequency parameter is :—

$$\lambda=\frac{2\pi fc}{V},$$

which is 2π times the ratio of the times just given. At low values of λ, i.e. less than say 0·20, the conditions assumed in the theory given so far may be taken to apply : at high values, i.e. greater than 1·0, then substantial corrections to this formula may be expected.

For aircraft compressors of modern design, the frequency parameter for fundamental flexural modes is between 0·1 and 0·3, but for torsional and higher modes it may be much greater. The theory is only true for flexural damping, there being no similar simple theoretical damping for torsional vibration, although damping derivatives may be derived theoretically if potential flow conditions are assumed through the cascade.

A great deal of emphasis has been placed in some quarters on the bending and torsional frequency parameters as affecting blade vibrations. This appears to have been due to the fact that there is a connection between frequency parameter and design gas bending stress (Appendix II). If it is assumed that there is a

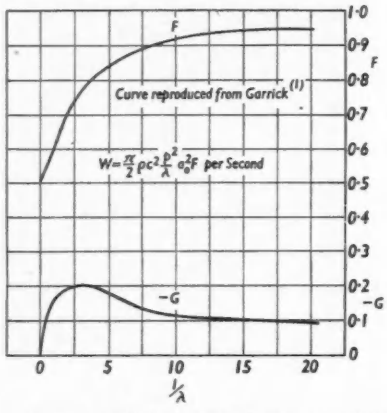


Fig. 1—Energy Dissipated by Flapping Aerofoil at Different Frequency Parameters

relation between vibrational stress and design gas bending stress then it follows that there ought to be a relation between vibrational stress and frequency parameter.

The variation of the damping with frequency is illustrated in Fig. 1 for an isolated aerofoil, the results being theoretical potential solutions.[1] It will be seen that even at infinite frequency parameter there is still damping of half the value at zero. Should aerodynamic excitation follow the same law, it is unlikely that a high frequency parameter would alter the nature of the problem very greatly.

Aerodynamic Instability—Flutter

Classical Flutter.—By analogy with the isolated aerofoil, the first possibility of blade excitation that arises is that of classical flutter, that is, coupled flexural-torsional oscillations. Because the centre of mass of the blade does not normally coincide with the torsional axis, flexural motions of the blade tend to excite torsional oscillations as well, i.e. there is coupling. By simple reasoning it may be shown that the coupled oscillations are either in or out of phase (0 deg. or 180 deg. phase difference). In either case no excitation can result from this coupling. When there is air flow over the blade, however, the motion of the blade causes an apparent change of incidence which causes an additional force to act (which is 90 deg. out of phase with the other motions of bending and twisting). This force acts through the aerodynamic centre of the blade section, which again will not usually coincide with either the mass or torsional axes. The effect of this force will be to alter somewhat the phase relationship of either 0 deg. or 180 deg. between torsional and flexural motion, the amount obviously depending on the velocity and density of the air over the blade. This phase difference enables energy to be absorbed from the air flow, and when the energy is enough to offset the damping present, the blade oscillations will grow and flutter will result.

There are many factors that have to be taken into consideration and the subject has been intensively studied for aircraft wings. For any given arrangement, there is a critical flutter air speed at which self-induced oscillations begin. This critical flutter speed depends on the positions of the centres of mass and torsion and the aerodynamic centre, but also it may be raised to a high value by increasing the wing flexural

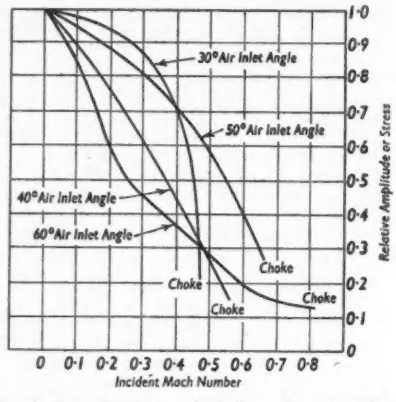


Fig. 2—Air Damping of Turbine Cascade Blade. Blade Forced to Vibrate at First Flap Frequency by Loudspeaker (Loudspeaker Unadjusted During Complete Run Through Mach Number Range)

and torsional stiffness. Calculations made for axial compressor blades have always shown that, because of the high blade frequencies, classical flutter could not occur until very large air speeds were attained, in which case the assumptions made in deriving these results would no longer apply.

No cases of coupled flexural-torsional flutter have ever been reported for compressor blades, and it is usually agreed that such flutter has little or no importance for compressor blading.

Stalled Flutter—Flexural.—As described in the introduction, when axial compressors of high compression ratio were built failure of early stage blades began to occur and it soon became evident that this was associated with running at speeds a good deal lower than design. It was immediately guessed that the failures were probably due to the stages stalling. Tests on a cascade of compressor blades showed that with most blades flutter was set up at the stall and was so violent that rapid failure of the

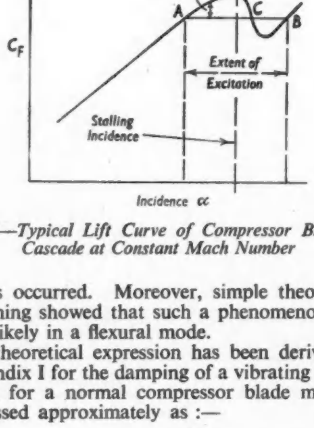


Fig. 3—Typical Lift Curve of Compressor Blade in Cascade at Constant Mach Number

blades occurred. Moreover, simple theoretical reasoning showed that such a phenomenon was very likely in a flexural mode.

A theoretical expression has been derived in Appendix I for the damping of a vibrating blade, which for a normal compressor blade may be expressed approximately as :—

$$\pi^2f^2\rho V\,ca^2\frac{\partial C_F}{\partial\alpha}$$

per unit length per second. Now this is only a positive quantity so long as $\partial C_F/\partial\alpha$ is positive, i.e. so long as the lift force increases with incidence. For most compressor blades, however, as the stall is reached and exceeded the lift falls off with incidence, although it may eventually recover again. Fig. 3 shows a typical curve of lift coefficient against incidence for a cascade of compressor blade sections at a constant incident Mach number. Over the whole of the unstalled portion of the curve the lift is increasing with incidence, but at the stall it reaches a maximum value after which it falls, afterwards recovering again. In this stalled region, where negative slope lift is obtained, self-maintained vibrations should occur.

In this region, when the blade is vibrating, energy is being absorbed from the air. Ignoring mechanical damping, the only factor preventing vibrations building up infinitely large is the finite extent of the negative slope region in Fig. 3. It might be thought at first that this would set the limit to the amplitude of oscillation, but a little consideration will show that energy will be absorbed by the blade while vibrating so long as the lift at the new value of incidence (assumed reduced) is higher than that at the undisturbed working point. In fact, in Fig. 3, assuming the undisturbed incidence corresponds to the point *C*, then vibrations over such an amplitude that the effective incidence reaches the values at *A* and *B*, will absorb energy from the air stream. Beyond this amplitude the excitation will be reduced, until eventually there will be damping. Hence the line *AB* represents, in the absence of

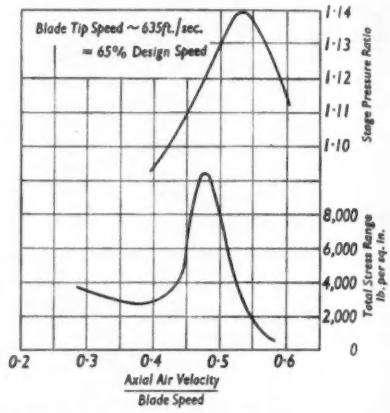


Fig. 4—Four-stage Compressor. First Stage Rotor Blade Fillet Stresses Under Stalled Conditions. Fundamental Flexural Mode. 200 c/s.

mechanical damping, the minimum expected amplitude of vibration. (Appendix III).

Assuming that $AC=CB=\alpha_v$, the amplitude of vibration is given by

$$a=\frac{\alpha_v V}{2\pi f}.$$

Also assuming that the blade is a simple cantilever of length h, then :

$$2\pi f=3\cdot52\frac{K}{h^2}\sqrt{\left(\frac{E}{\rho_m}\right)}$$

and the root stress is given by :

$$1\cdot76\frac{Eat}{h^2},$$

which reduces to :

$$\frac{\alpha_v V}{2}\frac{t}{K}\sqrt{(\rho_m E)},$$

For a simple prismatic section of aluminium alloy material this gives root stress (lb/in^2)= $18\cdot6\alpha_v V$.

For $V=600$ft per second and $\alpha_v=6$ deg. (typical figures) the root stress is 67,000 lb per square inch. This enormous stress would break the blade root immediately. On this simple basis the limit set by the cessation of excitation can be ignored, the only damping which need be considered is blade material and root fixing damping, provided that the blade is stalled over its whole length.

Another important result that emerges from this simple investigation is that for given aerodynamic characteristics there is little that can be done to reduce the root stress. The factor t/K is a function of the blade root shape which may be regarded as fixed, so that for a given blade material the root stresses are independent of blade length and thickness. This, at first sight, peculiar result only follows if other forms of damping are absent ; obviously the thicker the

blades the more important will material damping become.

For different blade materials the root stress is proportional to $\sqrt{(E\rho_m)}$. However, as a criterion for a blade material the ratio of root stress to failure stress, in this case some particular value of the fatigue stress of the material, is of more interest. Some figures for various metals, compared on the ratio of $\sqrt{(E\rho_m)}$ / (fatigue stress), are :—

Metal	E (lb/in²)	Specific gravity	Fatigue stress : 10^3 reversals (tons/in²)	$\sqrt{(E\rho_m)}$ / Fatigue stress
Aluminium alloy RR.56	$10{\cdot}3\times10^6$	2·75	10·7	$0{\cdot}498\times10^3$
Steel S.61	$29{\cdot}7\times10^6$	7·73	25·0	$0{\cdot}605\times10^3$
Steel S.62	$29{\cdot}7\times10^6$	7·73	34·5	$0{\cdot}425\times10^3$
Aluminium bronze	$16{\cdot}0\times10^6$	7·47	23·0	$0{\cdot}475\times10^3$
Titanium	$15{\cdot}5\times10^6$	4·50	30·0	$0{\cdot}274\times10^3$

Apart from the outstanding case of titanium, there is really very little variation and so theoretically no advantage in using steel instead of aluminium because, although the failure stress is greatly raised, the stresses set up during flutter

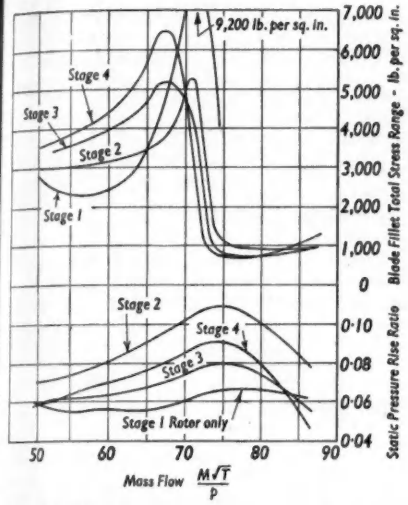


Fig. 5—Four-stage Compressor. Fillet Stresses Under Stalled Conditions and Static Pressure Rise. 5000 *r.p.m.*

are proportionately greater. However, there would undoubtedly be advantages in that, the stresses being so much higher for given blade deflections, the effect of other forms of mechanical damping would probably be enhanced.

In considering detailed results on blade stalling it is convenient to consider cascade and compressor tests separately.

Compressor Tests on Stalled Flutter.—The results of compressor tests are much more difficult to interpret. In the first place unless detailed surveys of air flow have been made, it is not possible to state definitely what are the incident conditions even on the first stage blades of a rotating compressor. Then most probably all the sections of the blade will not stall simultaneously, so that when, for instance, the blade tip is being excited most by the air flow, the rest of the blade may be damping vigorously, and vice versa. In fact, the interpretation of stalled flutter on an axial compressor involves all the uncertainties involved in assessing the aerodynamic performance.

There is also an effect—called here rotating stall—which enters to complicate the situation still further.

Fig. 4 shows the results of vibration measurements made on the first stage of a four-stage rig. The air flow was varied at fixed compressor speed well over the first-stage stall. The only significant stresses recorded occurred in the fundamental flexural mode, in this case at about 200 c/s. The stress begins to rise just after the stage stall (as defined by the peak of the stage pressure characteristic) and reaches its peak at a value of 10,000 lb per square inch range (i.e. ±5000 lb per square inch) after which it is reduced rapidly to the order of 2000 lb per square inch. Also shown is the stage pressure characteristic for the compressor, against values of the ratio v_a/u, i.e. ratio of axial air to blade velocity.

At $v_a/u=0{\cdot}53$, from analysis of air flow tests on this compressor, it has been found that the tip just begins to stall. This causes a reversal of flow through this part of the blade, the effect being to increase the air flow through the rest of the blade, thus tending to keep this unstalled. At $v_a/u=0{\cdot}475$ this stall has spread some 3in down the blade (the overall length of the blade is 7in) and in this condition the stress is a maximum. At $v_a/u=0{\cdot}425$ the stall has spread to 4in down the blade, while at $v_a/u=0{\cdot}35$ the whole blade is stalled.

From simple cascade tests, it would be expected that the stage would stall at about $v_a/u=0{\cdot}53$ and that the maximum excitation would occur at somewhat lower flow than this. But the phenomenon of stall in a cascade and a compressor stage appear to be quite different, the stall beginning at one point as a recirculation of flow, the rest of the blade being unstalled. Whatever the details, the net effect is to keep the blade stresses to a much lower figure than might be expected, but still high enough to cause fatigue failures. The stresses measured in the test quoted were at 65 per cent of design speed ; at higher speeds they would be larger, but on the other hand, it is not usual for first-stage compressor blades to stall above 75 per cent of the design speed when fitted to the full compressor.

Figs. 5 and 6 show results of stress measurements on all four rotor blades of this same four-stage compressor, at 5000 and 4000 r.p.m., respectively, as the mass flow is varied. At 5000 r.p.m. it will be seen that all four stages start to flutter at approximately the same flow, but the stresses, roughly uniform, in stages 2, 3 and 4 are somewhat below those in stage 1. The static pressures measured in the compressor show that all four stages are reaching the stall at roughly the same flow, which agrees with the stress results.

At 4000 r.p.m. the flutter does not occur at the same flow for all stages and again this is in agreement with the stage characteristics as given by the static pressures. Three things are noticeable from this result : first, the stresses in stages 2, 3 and 4, again roughly uniform, are

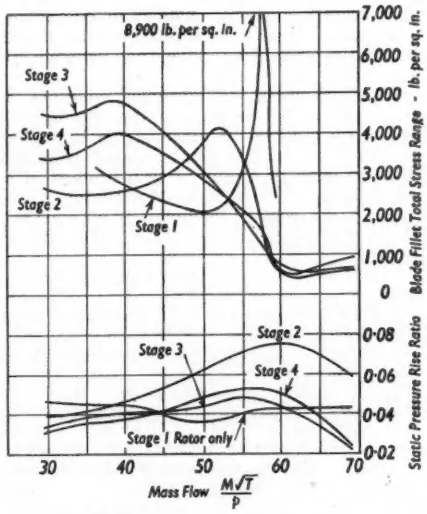


Fig. 6—Four-stage Compressor. Fillet Stresses Under Stalled Conditions and Static Pressure Rise. 4000 *r.p.m.*

only one-half that in stage 1 ; secondly, the stress peaks are by no means as sharply defined as that in stage 1, and, thirdly, it seems likely that the stalling and flutter of a stage has some effect in raising the stresses on the succeeding stages.

Tests made on a rotating rig in which the blade length was so small that the blades were of constant section, showed much better agreement with the results of cascade tests. Unfortunately no stresses were measured, but as soon as the compressor was taken just beyond the stall at any reasonable speed, complete failure of the blades occurred rapidly. This was in spite of very stiff and robust blade sections, and the frequency parameter was very high. Obviously the stress had been very high as in the cascade tests. Moreover it was possible to do a complete test on a section of high camber and low outlet angle (where the cascade tests showed little or no excitation), but several attempts at tests with blades of lower camber and larger outlet angle resulted in failure.

The effect of different blade materials has been checked in the same manner, using blades of steel and aluminium for comparison. It was found that the stresses in the steel blades were approximately 2·4 times those for aluminium. This is in close agreement with the predicted ratio deduced earlier, that the stresses should be proportional to $\sqrt{(E\rho_m)}$, and indicates little improvement from using steel in place of aluminium in this respect.

Rotating Stall.—Differences between the stalling behaviour of a compressor blade and a stationary cascade have already been pointed out. There is an additional effect with the

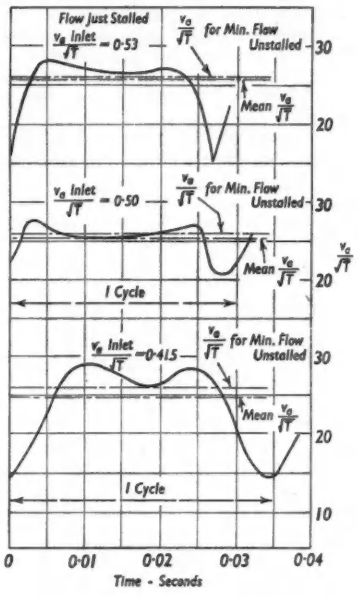


Fig. 7—Rotating Stall. Four-stage Compressor. 78 *per cent of Design Speed* (6000 *r.p.m.*). *Analysis of Conditions at Outlet*

compressor blade which is of interest for the possibility of exciting blade vibration.

Failures occurred during development of a later stage of a compressor. The failure showed a clear case of fatigue and appeared to be in the fundamental flexural mode. It was clear that at this frequency the excitation could not have arisen from the presence of any webs, struts, and so on, and it was equally clear that this particular stage was not stalled. However, at the low speed at which most of the running before failure had been done (65 per cent of the design speed) as many as six stages were stalled at the front of the compressor. It is not difficult to imagine that in these circumstances the air flow would be considerably disturbed and might create wakes which could excite this blade, farther back in the compressor, to vibrate.

It was interesting to pursue this speculation a little further. It is known that in symmetrical annuli it is difficult to create a stalled flow and to keep this located symmetrically all the way round the annulus. What often happens is that the stalled portion occurs at one point, the rest of the flow being unstalled. This stalled portion may in some cases rotate round the annulus or fluctuate from one point to another. In the compressor annulus therefore something similar would be expected, one part of the annulus being stalled and the rest unstalled. It is clear, however, that the stalled portion would not remain stationary since then the stators at this point would remain stalled permanently, while the rotor blades would be alternately stalling and unstalling as they moved through the region. The only way to put rotors and stators on a similar basis is for the stalled region to rotate

in the direction of compressor rotation, at half the speed of the blades. Then the stalled region is moving at the same relative velocity past rotors and stators. Of course, it is not necessary that rotors and stators should be exactly the same, so that some deviation from this figure of half speed might be expected.

This rotating wake passing through the compressor would be a source of blade excitation to the various stages, whether stalled or not, and might also affect stalled flutter in the stalled stages. Accordingly, this phenomenon has been examined in several compressors and found to exist when several stages are stalled, although it has not been found in all designs.

Total head pick-ups were inserted through the compressor casing after the first four stages of a multi-stage compressor and also at entry to the compressor. By using two pick-ups suitably spaced round the annulus and measuring the phase between each record, it was possible to estimate the rate of rotation of any disturbance. The analysis of these records showed the rotational speed of the stall to be between 35 and 40 per cent of compressor revolutions per minute, the shape of the stalled portion at outlet being as shown in Fig. 7. The main portion of the air flow remains at about the minimum for unstalled flow, while sharply defined stall pulses move round the annulus. The amplitude and extent of these pulses depend upon the mean mass flow ; as the stage becomes more and more

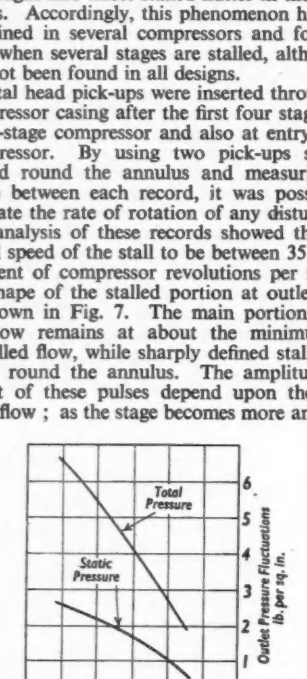


Fig. 8—Rotating Stall. Four-stage Compressor. 78 per cent of Design Speed (6000 r.p.m.). Frequency and Amplitude of Pressure Fluctuations

stalled, the pulses broaden out until they fill the whole annulus. The actual values of pressure amplitude and rotational frequency are shown in Fig. 8.

At lower values of revolutions per minute it was found that the number of pulses existing round the annulus at any given time could sometimes increase to as many as six, the actual number varying rather spasmodically. Because the pulses are not of simple sinusoidal shapes and may therefore be expected to excite plenty of harmonics, the possibility of a wide range of exciting frequencies exists, which may cause blade failures of either the stalled stages or blades somewhat farther back.

When this phenomenon was first investigated it was thought optimistically that because, as in Fig. 7, the main air flow remains unstalled, stalled flutter would be absent, the main effect of stalling being to produce rotating wakes which would cause buffeting of the blade. If the forcing frequency (or a harmonic) of these was in resonance with the blade, large stresses would be set up ; if not, no harm would be done.

This hope was not borne out. Stress measurements showed that, in spite of the rotating stall, stalled flutter was present all the time, although evidence of variation of the flutter level at the frequency of the stall rotation was obtained. Perhaps an explanation of this is that the main flow in the annulus is just stalled enough to excite blade vibrations, as the accuracy of Fig. 5 (owing to the method of measurement) is necessarily low.

This explains the general " grumbling " noise made by axial compressors when running at low speeds. As a rule the noise suddenly stops after a certain speed is passed, corresponding to the unstalling of the first stage. It was confirmed that the phenomenon disappeared on this particular compressor at the same time as the noise.

Since the foregoing was written, reports of similar work done in the United States have been published.

Conclusion

In a short summary of this paper the following points emerge :—

(*i*) In the unstalled region the damping present is almost wholly aerodynamic even when excitation is aerodynamic, e.g., from wakes and so on.

(*ii*) When wakes are present the resulting vibration may be assessed from the equality of aerodynamic excitation and damping, other damping being negligible by comparison. Such considerations lead to simple expressions for blade stresses resulting from such wakes.

(*iii*) These wakes die out rapidly in a compressor and should not affect blades after, at most, two stages from the start of the wake.

(*iv*) A prime cause of blade failure is unidimensional flutter when the stage is stalled in a high pressure ratio compressor. Initially thought to be a most powerful phenomenon, it appears that is it more likely to be merely the absence of any degree of damping that causes the high stresses to be set up, and that a modest degree of " built-in " damping would probably eradicate it.

(*v*) A great deal more work on cascade rigs and rotating stages is required in connection with stalled flutter, to investigate the flutter boundaries when blade stiffness and damping are varied.

(*vi*) Little work on torsional vibration is contained in this paper. So far, few failures have been ascribed to torsional vibration, but as such a statement in a paper usually coincides with the onset of a crop of such troubles, it is suggested that more work be done on this.

The paper included the following appendices :

No. I.—" Aerodynamic Damping—Flexural Mode."

No. II.—" Frequency Parameter and Bending Stress."

No. III.—" Amplitude Limit of Stalled Flutter Vibrations."

No. IV.—" Aerodynamic Excitation From Wakes, &c."

No. V.—" Resonance Peaks."

No. VI.—" Damping and Stalled Flutter."

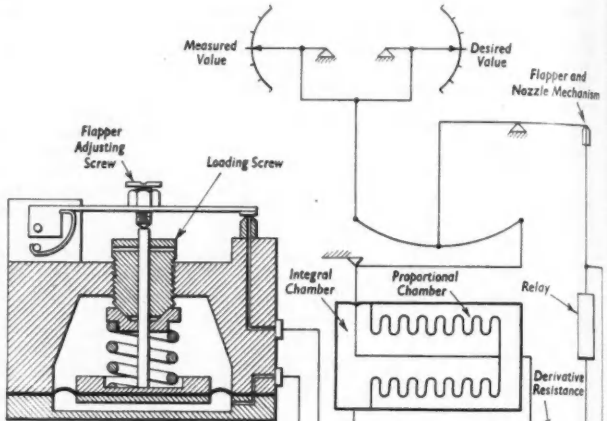
Reference

[1] Garrick, I. E. (1936). Propulsion of a Flapping and Oscillating Aerofoil. N.A.C.A. Report 567, 1936.

An Automatic Bleed Unit

Conventional automatic controllers employing integral action may have some disadvantages when used on discontinuous or batch processes. An " overshoot " of the measured variable tends to occur when the variable returns to its desired value after an interruption of the process.

The integral function of a controller is constantly in operation while the measured variable deviates from the desired value ; in consequence, if there is a prolonged interruption of the process, the integral action will build up until it reaches its limit, when it will become " saturated " and render the controller mechanism ineffective. In air-operated controllers this " saturation " occurs when the integral chamber pressure reaches its maximum, and the deviation will then cause the flapper (of the controller detecting mechanism, normally a flapper and nozzle) to be held outside its normal working range. The flapper does not re-enter its normal working range until the deviation is eliminated, the plant regulator meanwhile being at the limit of its travel. When plant conditions return to normal and the measured variable rises in response to the plant regulator position the controller is therefore unable to produce any corrective action until the measured variable has reached the desired value. An " overshoot " of the measured variable may therefore take place and possibly result in damage to the plant or impair the operation of the process. A device has now been developed by George Kent, Ltd., to eliminate this " overshoot." It is known as the " Automatic Bleed Unit " and is illustrated in the accompanying illustration.



Automatic Bleed Unit

This unit is connected to the integral chamber of the controller and the controller nozzle line, so that when an interruption of the process occurs and the control pressure reaches its maximum a " bleed " of air from the integral chamber takes place, thus retaining the flapper within its normal working range and keeping the controller mechanism effective. This action will occur continuously until plant conditions return to normal. In consequence, control action begins while the measured variable is returning to its desired value, thereby greatly reducing the possibility of " overshoot." The " Automatic Bleed Unit " consists essentially of a cast body enclosing a flexible diaphragm. This diaphragm is constrained by an adjustable control spring, as shown in the illustration. When the control pressure, which is applied below the flexible diaphragm, reaches its normal maximum and overcomes the control spring, the pivoted arm is raised, opening the nozzle valve connected to the integral chamber of the controller, and bleeding air from the integral chamber to atmosphere. The control spring is adjusted to correspond with the upper limit of the control pressure range by means of the loading screw at the top of the cast body.

This unit, we are informed by the firm, has been successfully employed in practice on control circuits for processes of the discontinuous type, including the control of open-hearth furnace roof temperature. Another example of " overshoot " elimination by this means is in automatic superheat control of boilers. The device can be added to the standard Kent Mk. 20 controller without affecting its performance or modifying its response characteristics.

Rye House Power Station.—The British Electricity Authority has received the consent of the Minister of Fuel and Power to the extension of Rye House power station, near Hertford, by two 32MW turbo-generator sets and two boilers, each having an evaporative capacity of 350,000 lb of steam an hour. When finally completed this station will have a total installed capacity of 192MW.

Industrial and Labour Notes

Production Control

This week the British Productivity Council has published the report of a specialist team on production planning and control, which visited the U.S.A. towards the end of 1951. The team was under the leadership of Mr. G. H. Way, chief planner of the Dunlop Rubber Company, Ltd., and its terms of reference were " to investigate the production methods and procedure from finality of the design stage to dispatch."

The report says that although little was seen with which the team was not already familiar, there is no doubt that the high output per man and the apparent smooth flow of work from start to finish were in no small measure due to careful planning and effective control. Three main recommendations are made in the report. They are : that every firm in Great Britain, large and small, should examine its present system of production planning in the light of the report ; that those firms which find that they are not at present operating an effective system on the lines indicated in the report should establish a system to meet their needs without delay ; and that small firms should devise a system which will meet their own special requirements. To this last recommendation, the team has added the comment that it is no excuse for a small organisation to say that it cannot afford production planning and control ; an efficient and simple system will undoubtedly result in increased productivity.

In its conclusions leading to these recommendations, the team says that American managements have recognised that the first essential in planning for production is to know the markets for the product which the company intends to manufacture, and that in assessing these markets very extensive use is made of past history and of statistics. In the formulation both of the forecast and the production plan, the team was impressed by the very close co-operation that existed between design, sales and production. There was plenty of evidence of a concentration on specific kinds of product, and it appeared to be the aim of all firms to reduce the number of kinds of product to the minimum and thus to obtain the longest possible production runs. Even where products were manufactured to customers' requirements, the report states, every possible use was made of standard parts and sub-assemblies, a factor which was reflected in the ultimate low cost of the end-product. Another important factor which the team noted was that plant and equipment were invariably installed to work on a two or three-shift basis, which again made a large contribution to low cost. In a general survey of its tour, the team says that the meticulous attention to detail which characterised each planning stage was matched and equalled by the efficiency with which the manufacturing programmes were executed, through control of production, particularly on the shop floor. The drive to meet the plans through effective production control rather than alter the plans to suit circumstances was a noticeable point in the organisation of most of the American firms visited.

Education and Productivity

In a speech at Lancaster on Friday last, Mr. Lincoln Gordon, Minister for Economic Affairs at the American Embassy, said that the current display of renewed and intensive interest in this country in education for industry was most encouraging for Britain's economic future, for it meant that early action could be expected to expand and improve training facilities. But, he added, there were some dangers. Education was not a panacea, and it would be unfortunate if industry, the Government or the public at large felt that merely adding extra courses and building new schools would automatically solve all the problems of productivity.

Mr. Gordon went on to say that the battle for higher productivity must be fought on all fronts at once. There must be the incentive and the will to employ better methods and better equipment and there must be the ability to finance the requisite investment. Management and labour alike must become persuaded that economic expansion and higher productivity were the only open frontiers for improving the material welfare of the entire community. Improved educational facilities, Mr. Gordon asserted, would not help greatly if men and women of ability did not feel that an industrial career offered the satisfaction of personal challenge and opportunity for full use of their capacities. The best minds would not avail themselves of such training unless leadership in industry commanded higher public esteem.

Mr. Gordon also said it would not be disputed that the best technological training in Britain was second to none. It would be to the ultimate advantage of industry and the nation that men with engineering backgrounds should reach the higher posts of industry in greater numbers, for with their knowledge of the possibilities of technology they were more likely than any other group to infect the spirit of expansion and innovation into the body of industry.

Tinplate and Terneplate Prices

After consultation with the Iron and Steel Board, the Minister of Supply has made the Iron and Steel Prices (No. 5) Order, 1953, which relates to tinplate and terneplate prices. The effect of the Order is to increase, as from October 1st, the basis prices for tinplate by 1s. 8d. a box, and for terneplate by 6d. a box. In consequence, however, of the price changes resulting from the operation of the " automatic variation adjustments " for tin and lead, the maximum prices for tinplate and terneplate remain unchanged. The Ministry says that the purpose of this Order is to continue temporarily the stabilisation of the maximum selling prices of tinplate and terneplate pending further examination of these prices by the Iron and Steel Board.

The British Productivity Council

The British Productivity Council has issued a bulletin surveying its recent activities and giving details of the various ways in which it is ready to assist industry. A statement entitled " The Approach to the Job," which is included in the bulletin, contains particulars of the growth and development of the local productivity committees which have been and are being established throughout the country.

The statement says that the first task of these local productivity committees, before attempting to formulate their programmes of action, has been to assess the nature and magnitude of the problems facing them. In so doing, they have naturally concentrated more on local than on general productivity problems, though, it is explained, the latter will undoubtedly have a place at their discussion and lecture meetings. Some local productivity committees, it is explained, have made their surveys through personal calls on individual firms, and others by sending out questionnaires, but nearly all of them have recognised that exhortation is of little value, especially to those who are already converted to belief in the need for higher productivity. The more usual procedure, it is stated, has been for the local productivity committees to ask questions about such matters as the causes of absenteeism and high labour turnover, work study, payment by results and other systems of incentives.

In addition, most of the local productivity committees have announced their intention of arranging inter-factory team visits, which, the bulletin says, promise to be one of the most far-reaching aspects of their work. But if these visits are to be of real value, it is suggested that the teams should be carefully briefed and machinery should be devised for reporting back their findings. The bulletin adds that due consideration must be given to these findings at executive level, so that appropriate action can be taken, and, for this reason, it is urged that each team should include at least one representative of higher management.

Trade Prospects in Iraq

The Board of Trade has recently published a report on economic and commercial conditions in Iraq, which has been prepared by Her Majesty's Counsellor (Commercial) in Bagdad. The report says that that in order to achieve planned development, the Iraq Development Board was set up in 1950 and began to function a year later. The Board's long-term programme includes the building of dams and the development of irrigation, communications, industries, health services and education.

During the next few years, the report continues, there should be an appreciable market for capital equipment required for the various development projects to be carried out for the Iraq Government and financed mainly through the Development Board. Moreover, it is believed that these projects will continue to offer opportunities for participation to consulting and contracting engineers, although it should be noted that competition is becoming increasingly keen in this field. The report comments that, in recent years, United Kingdom firms have done well and that their reputation stands high in Iraq, but, it is added, " They will have to be prepared to meet competition from firms of other nationalities."

The Coal Situation

A statement on the coal situation, issued by the Ministry of Fuel and Power, shows that in the first thirty-nine weeks of this year the saleable output of coal totalled 165,106,400 tons, which was about 2,500,000 tons below the amount raised in the comparable period of last year. Of the total, 156,259,900 tons came from the deep mines and 8,846,500 tons from opencast workings. The saleable output last week amounted altogether to 4,526,900 tons.

In the week ended September 26th, there were 713,100 workers on colliery books, compared with 719,500 a year earlier. The proportion of face workers is now greater, however, the number on September 26th being 299,300. Absenteeism at that date was slightly less than a year ago, and the output per manshift at the face was 3·142 tons, compared with 3·153 tons on September 27, 1952. Inland consumption of coal in the week ended September 26th was 3,773,000 tons and the quantity taken up for exports and bunkers was 354,000 tons. This gave a total consumption during the week of 4,127,000 tons. The figure of distributed coal stocks has shown some improvement in recent weeks. On September 26th, stocks stood at 17,348,000 tons, compared with 18,726,000 tons a year earlier.

Private Trading in Magnesium

It has been announced by Lord Woolton, Minister of Materials, that it has been decided to restore private trading in magnesium on January 1st next. As from that date, the Ministry of Materials will cease to trade in magnesium and the Magnesium Distribution Order, 1951, will be revoked. Private imports will be permitted, and applications for import licences should be made to the import licencing branch of the Board of Trade. It will be recalled that public trading in magnesium was re-introduced two years ago because of a serious shortage which had developed throughout the world as a result of re-armament. The Ministry of Materials says that supplies are now such that the United Kingdom's requirements can be met through normal trade channels.

Notes and Memoranda

Rail and Road

INSTITUTE OF TRANSPORT AWARD.—At a meeting of the Institute of Transport on Monday last, the retiring president, Mr. C. T. Brunner, presented the Institute triennial award of merit to Sir Reginald Wilson, member of the British Transport Commission. The award, which takes the form of a bronze statuette of Pegasus, has been conferred on Sir Reginald Wilson for his paper on "The Framework of Public Transport," presented to the recent congress of the Institute of Transport at Glasgow.

RAILWAY CIVIL ENGINEERING.—An illustrated brochure entitled *Railway Civil Engineering as a Career* has been published recently by British Railways. It was prepared by the Railway Executive in association with the London Transport Executive and contains some helpful and interesting information about the requirements of railway civil engineering and about works undertaken by the civil engineering departments of British Railways. The brochure is being distributed to all universities and technical colleges and public and secondary schools throughout the country in order to bring to the notice of potential civil engineers the scope and nature of the training which the railways can give.

DUAL CARRIAGEWAYS FOR VICTORIA EMBANKMENT.—Yesterday, the Westminster City Council received from its Works and Traffic Committee a recommendation to proceed with a scheme for the reconstruction of the Victoria Embankment between Bridge Street, Westminster, and the Temple. The City of London is responsible for the section of the Embankment from the Temple to Blackfriars, and has already started work on an improvement scheme. The new layout envisaged in the Westminster Council's scheme includes two 28ft carriageways and a 6ft strip down the centre with space for flowers and shrubs. The total cost of the Westminster and City schemes is put at about £250,000.

RESEARCH AND ROAD SAFETY.—At the suggestion of the Ministry of Transport, the Road Research Laboratory of the Department of Scientific and Industrial Research is arranging an exhibition to show what research is doing to investigate problems of road safety. This exhibition will be held at the traffic and safety division of the Laboratory, Langley Hall, Langley, Bucks, and will be open on Wednesday, Thursday and Friday, October 21st, 22nd and 23rd, from 10 a.m. to 1 p.m. and from 2 p.m. to 5 p.m. Admission is by ticket free on application to the Director of Road Research, Road Research Laboratory, Harmondsworth, West Drayton, Middlesex. Applicants should indicate which day and which session they would prefer to attend. The exhibition will demonstrate problems of the road, the vehicle and the road user and will include such aspects as braking and skidding, visibility from vehicles by night and by day, and problems of crossing the road.

ROAD ACCIDENTS.—According to reports so far received by the Ministry of Transport, casualties on the roads of Great Britain in August totalled 21,829. This was 584 more than in August of last year and included 453 killed, an increase of fifteen. The total was, however, nearly 1000 fewer than in July, when casualties numbered 22,760, of which 430 were fatal and 5,551 seriously injured. Detailed figures for July, compared with those for the same month of last year, showed a marked rise in casualties to drivers and passengers. Casualties to drivers of motor vehicles, other than motor cycles, numbered 2064, an increase of 519 or over one-third; and casualties to their passengers numbered 4682, an increase of 495. The provisional figures for August bring the total number of casualties in the first eight months of the year to over 148,000, including 3161 killed. Compared with the same period last year, these figures show increases of over 10,600 in the total and 178 in the killed. The Ministry says that with the approach of the winter months, drivers and cyclists should take care to overhaul their lamps and make sure that they are correctly adjusted and in good working order.

WEMBLEY PARK PASSING LOOPS.—London Transport says that work is now in hand on the provision of an additional pair of running tracks north of Wembley Park Station, Middlesex, to eliminate the bottleneck caused by the existing layout of tracks at that point. At present, the Metropolitan line's fast and "stopping" services share a common track immediately north of the station (except when the local train can be routed over the Bakerloo line tracks) which can result in the transference of delays on either line. When the new works are completed, the Metropolitan fast and "stopping" services and the Bakerloo service will be completely segregated, to secure a significant improvement in Metropolitan line working, as well as making the Bakerloo line operations self-contained. The scheme involves the addition of a new span to a bridge over Forty Avenue, the widening of 300 yards of embankment north of the bridge, curtailment of the adjacent railway carriage sheds and the provision of about half a mile of new double track, together with the re-alignment of certain existing tracks and all necessary alterations to such matters as connections, signalling and power cables. The work has been arranged to avoid interruption to the train services.

CONFERENCE OF MINISTERS OF TRANSPORT.—Earlier this year, a European Inland Transport Conference was held under the ægis of the Organisation for European Economic Co-operation to study the existing organisation and regulation of international inland transport in Europe and to see whether they are adequate to make the best use of the existing transport system and for its rational development. All the members of O.E.E.C. were represented except the Irish Republic and Iceland; Spain and Yugoslavia participated and the U.S.A. sent observers. After discussing the report of this conference, the Council of O.E.E.C. recommended that a European Conference of Ministers of Transport should be established and that the Member countries which had been represented at the Inland Transport Conference should participate in the constituent conference. At the invitation of Monsieur Segers, the Belgian Minister of Communications, this constituent conference is to take place in Brussels from October 12th to 17th. Mr. Alan Lennox-Boyd, Minister of Transport and Civil Aviation, has accepted the invitation to attend this conference in Brussels and will lead the United Kingdom delegation for the first part of the conference. The Earl of Selkirk will lead for the second part. As expert advisers, the Minister will be assisted by Sir Cyril Birtchnell, K.C.M.G., and officials from the Ministry of Transport and Civil Aviation and from the Foreign Office.

Air and Water

THE LIFEBOAT SERVICE.—Lifeboats of the Royal National Lifeboat Institution were launched on service 328 times in the six summer months from April 1st to September 30th, and rescued 175 people. During this period eighty-six of the launchings were to help yachts and forty to search for possible survivors from aircraft.

ROYAL AERONAUTICAL SOCIETY.—The council of the Royal Aeronautical Society has announced that H.R.H. the Duke of Edinburgh, K.G., has graciously accepted Honorary Fellowship of the Society. Honorary Fellowship has also been conferred on Sir Geoffrey de Havilland, C.B.E., Sir Arthur Gouge, M.I.Mech.E., and Lord Hives, C.H.

KEEL LAYING CEREMONY.—On September 30th, the ceremony of laying a keel plate of the new Canadian Pacific liner was carried out by Mr. W. A. Mather, the President of the Canadian Pacific railway. The 22,500-ton liner, which is expected to join the company's fleet in 1956, is designed to carry 150 first-class and 900 tourist-class passengers, and to have a speed of 22 knots, and is being built by the Fairfield Shipbuilding and Engineering Company, Ltd.

EAST COAST SEA DEFENCES.—Soon after the East Coast Flood Disaster of January 31st last, the Minister of Agriculture set September 30th as the date by which the damaged sea defences should be rebuilt. Throughout the spring and summer, work has gone ahead without respite, and restoration in all areas is now virtually complete. The Ministry of Agriculture says that so far as can be assessed, the new defences will be as strong as and, in many places, far stronger than before the flood. There is, however, still some finishing off to be done, and to allow for this the Government has extended until December 31st the period within which the cost of restoration work will be fully reimbursed. The damage done last winter extended to over 1000 miles of coast-line and involved some 1200 breaches in the defences.

Miscellanea

ENGINEERING INDUSTRIES ASSOCIATION.—The sixth London Regional Display to be organised by the Engineering Industries Association is to take place at the New Horticultural Hall, Greycoat Street, London, S.W.1, on Tuesday, Wednesday and Thursday of next week, October 13th, 14th and 15th. The display will include examples of the products of about 150 member firms of the Engineering Industries Association, and the opening ceremony will be performed at 11.30 a.m. on Tuesday morning by Sir James Helmore, Permanent Secretary to the Ministry of Supply. The display, free of charge, is open to all who are engaged in the engineering and allied industries. Admission is by ticket obtainable from the Engineering Industries Association, 9, Seymour Street, London, W.1, or by the presentation of a business card.

HARWELL ISOTOPE SCHOOL.—The Ministry of Supply states that interest in the growing use of radio-active isotopes throughout the world and the demand from universities, hospitals and industrial organisations abroad has compelled the isotope school at Harwell to introduce an additional course for the second time this year. The school was started at the Atomic Energy Research Establishment two years ago to teach the techniques of using and handling radio-active materials to scientists, doctors and industrial research workers. The series of courses planned for this year did not include one for July, but one had to be arranged and was filled. There is still a heavy demand for places and another extra course will be held from November 16th to December 11th. Applications for this course should be sent to the Isotope School, A.E.R.E., Harwell, Berkshire, as soon as possible.

WORLD POWER CONFERENCE.—The annual meeting of the international executive council of the World Power Conference was held last month in Western Germany and was attended by thirty delegates from seventeen different countries. At the meeting, invitations for the fifth World Power Conference, to be held in 1956, were issued by the national committees of Austria, the German Federal Republic, and Yugoslavia. Unless two of these invitations are withdrawn, it will be necessary to hold a special session of the international executive council to decide, by a majority vote, which invitation is to be accepted. The intention is that, should it be required, this special meeting of the council shall be held in London in November. The annual executive meeting of the International Commission on Large Dams was held in Paris last month. Among the matters discussed was the programme for the fifth International Congress on Large Dams, which is to take place in Paris in 1955.

MR. R. HENDERSON.—We record with regret the death, on September 27th, of Mr. R. Henderson, who was an engineer in the traction department of British Insulated Callender's Construction Company, Ltd., at Kirkby. Mr. Henderson joined the contracts department of the former British Insulated Cables, Ltd., in 1920, and was subsequently associated with many overhead line contracts in this country and abroad. In 1928 he was engaged on transmission line erection for the Perak hydro-electric scheme in Malaya, and in 1935 he supervised the railway electrification work being undertaken for the Central Railways of Brazil.

POWDER METALLURGY.—The latest uses of and production methods in powder metallurgy are being studied by a team of experts which arrived in New York on September 30th. The team, whose mission has been organised under the technical assistance scheme of the Organisation for European Economic Co-operation, consists of twenty-eight representatives from Belgium, Denmark, France, Germany, Italy, the Netherlands and the United Kingdom. The members of the team are visiting industrial undertakings all over the United States during their five-weeks tour. On completion of their tour, the experts will report on possibilities of increasing European productivity in an industry which has reached a high degree of development in the United States.

MR. R. W. BEDFORD.—We have learned, with regret, of the death of Mr. Richard W. Bedford, contracts manager of George Kent, Ltd., Luton, which occurred, following some months of illness, on Saturday last, October 3rd. Mr. Bedford had spent by far the greater part of his working life with George Kent, Ltd., which he joined in June, 1904, when the firm's main factory was in London. He moved to Luton in 1908 when the Biscot Road factory was opened, and was appointed works manager there in 1919. Mr. Bedford was responsible for much of the work involved in the equipment of the factory taken over by George Kent, Ltd., at Resolven, South Wales, in 1946, in which year he was appointed contracts manager for the firm. He was a member of the Institution of Production Engineers.

Personal and Business

SHARPLES CENTRIFUGES, Ltd., states that Mr. Ian McLeod has joined its process engineering division.

TUBE INVESTMENTS, Ltd., has acquired the whole of the shares of the Round Oak Steel Works, Ltd., Brierley Hill, Staffs.

MR. J. E. COOK has been appointed regional manager of the north-east region of Fina Petroleum Products, Ltd., at Gunness, Lincs.

W. EDWARDS AND CO. (LONDON), has moved from Worsley Bridge Road, Lower Sydenham, to Manor Royal, Crawley, Sussex.

BROUGHTONS ENGINEERING GROUP, 10, Victoria Rise, London, S.W.4, states that its telephone number has been changed to Macaulay 8000.

DAVID BROWN TRACTORS (ENGINEERING) Ltd., announces the appointment of Mahindra and Mahindra, Ltd., Bombay, as sole concessionaire for its tractors in India.

THE ENGLISH ELECTRIC COMPANY, Ltd., has transferred its Manchester office to Croxley House, 14, Lloyd Street, Deansgate, Manchester, 2 (telephone, Deansgate 7872.)

THE BRITISH WELDING RESEARCH ASSOCIATION states that Dr. A. A. Wells has been appointed chief research engineer and head of the engineering research station at Abington, near Cambridge. Mr. R. P. Newman has been appointed chief administrative officer of the station.

THE MINISTER OF SUPPLY has appointed Air Commodore H. D. McGregor, C.B., to a new post in the guided weapon headquarters organisation, with the acting rank of Air Vice-Marshal. He will be responsible for guided weapons for the services during the later stages of their development.

INSURANCE ENGINEERS, Ltd., 23-31, Great Titchfield Street, London, W.1, states that Mr. A. K. Warner will retire at the end of the year from his position of chief engineer and manager, and will be succeeded on January 1st by Mr. W. H. Forster, Mr. E. J. Walker is to become assistant chief engineer and manager.

THE ALLIS-CHALMERS MANUFACTURING COMPANY, Milwaukee, U.S.A., is forming a new company in this country to handle its British business and the business of export markets which can be conveniently served from the United Kingdom. The parent company already has a branch at Totton, Hants, and a factory at Essendine, Lincs. The board of the new company will include Mr. W. A. Roberts, president of the parent company, Mr. E. J. Mercer, general manager of the English branch, and Mr. M. M. Tulloch, London manager of the general machinery division.

THE DELCO-REMY-HYATT division of General Motors, Ltd., 111, Grosvenor Road, London, S.W.1, announces the impending retirement of the general manager, Mr. W. A. Crewe, after more than thirty years service. The following managerial changes were made on October 1st: Mr. C. H. Charles, executive assistant to the general manager; Mr. W. B. Jones, general sales manager, and Mr. S. Jackson, assistant general sales manager. Mr. L. Bell has been appointed supply manager in succession to Mr. G. E. Elen, who is taking up new duties in the Frigidaire division of General Motors, Ltd.

British Patent Specifications

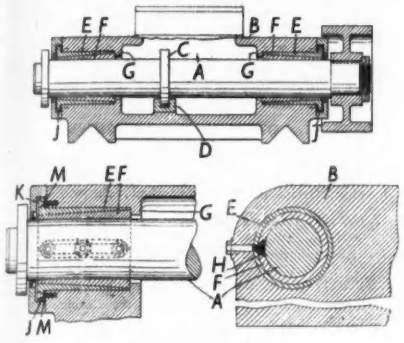
When an invention is communicated from abroad the name and address of the communicator are printed in italics. When an abridgment is not illustrated the specification is without drawings. The date first given is the date of application; the second date, at the end of the abridgment, is the date of publication of the complete specification.

Copies of specifications may be obtained at the Patent Office Sales Branch, 15, Southampton Buildings, Chancery Lane, W.C.2 2s. 8d. each.

MACHINE TOOLS

696,140. October 9, 1950.—SHAFT BEARINGS, The Churchill Machine Tool Co., Ltd., Atlantic Street, Broadheath, Manchester, and George Herbert Asbridge, of the company's address.

The invention is concerned with the means by which shaft bearings can be adjusted to give a predetermined clearance and can be locked in the adjusted position. As the drawing shows, the shaft *A* is mounted in bearings at the opposite ends of a housing *B*, which contains oil, there being a collar *C* on the shaft which revolves in a channel member *D* secured to the housing to prevent axial movement of the shaft. Each bearing comprises two sleeves, an outer one *E* which has a cylindrical periphery to fit a cylindrical bore in the housing and a tapered bore, and an inner split sleeve *F* which has a tapered peripheral surface to fit in the tapered bore of the sleeve *E* and a parallel bore to fit upon the shaft *A*. There is an internal flange *G* in the housing to provide an abutment for the end of each inner sleeve *F*. The adjacent ends of the split sleeve *F*



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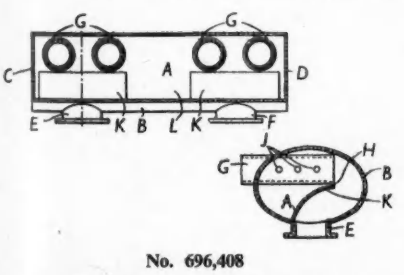
are tapered as shown to provide a wedge-shaped gap at the split and into such gap fit three dovetail nuts *H* on bolts which extend radially through the outer sleeves *E* and the housing. The sleeves *F* are brought against the abutments or shoulders *G* in the housing and the sleeves *E* are then placed on the sleeves *F* and pushed into the housing until due to the taper of the two sleeves, the sleeve *F* is closed in to the desired clearance around the shaft. There will then be a clearance between the flange *J* on each outer sleeve and the end of the housing. Into these clearances are fitted "C"-shaped spacing washers *M* and the screws *K* which lock the sleeves to the housing are tightened in order to preserve the adjustment. The bolts carrying the dovetail nuts *H* for locking the inner sleeves within the outer sleeves are now tightened. The housing and the pairs of sleeves then form a solid construction. By varying the thickness of the spacing washers fitted between the flanges *J* and the housing, the bearing clearance can be adjusted as desired and locked in the adjusted position.—*August* 26, 1953.

INTERNAL COMBUSTION ENGINES

696,408. April 1, 1952.—SILENCERS FOR EXHAUST GASES, The Maxim Silencer Company, Homestead Avenue, Hartford, Connecticut, U.S.A.

Referring to the form shown in the drawing, the silencer is formed with a single chamber *A* enclosed



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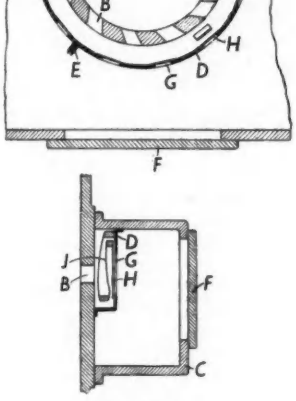
by a cylindrical shell *B* preferably of elliptical cross section and end headers *C* and *D*. Inlet conduits *E* and *F*, generally connected to the two exhaust manifolds of a "V" engine, open into the chamber *A*. Preferably the inlet conduits are arranged in line with the minor axis of the ellipse. The four exhaust conduits *G* are arranged parallel to the major axis of the ellipse, and as far away from the inlet conduits as is consistent with having the exhaust conduits extending somewhat beyond the centre of the chamber *G*. The open ends of the exhaust conduits are flared at *H* to reduce entrance losses and are provided with anti-resonance holes *J*. Within the chamber a deflecting plate *K* secured to the shell is curved over the inlet opening and extends to the flared ends *H* of the exhaust conduits to direct the gas against the shell wall rather than allowing it to pass straight into the chamber. Preferably the plate is formed with a central gap *L*. Modifications of the form of the deflecting plates are also shown in the specification.—*August* 26, 1953.

696,583. August 16, 1950.—SCAVENGING OF TWO-STROKE ENGINES, Aktieselskabet Burmeister and Wain's Maskin og Skibsbyggeri, 4, Strandgade, Copenhagen, Denmark.

In the drawings a cylinder *A* has a ring of inlet ports *B* at one end of its working space controlled by a working piston and scavenged by air through these ports to an exhaust at the other end of the space. The ports are surrounded by a scavenging air belt *C* which is of large volume and serves all the cylinders. The annular partition *D* with which the invention is particularly concerned, defines a space around the ports *B* which is relatively



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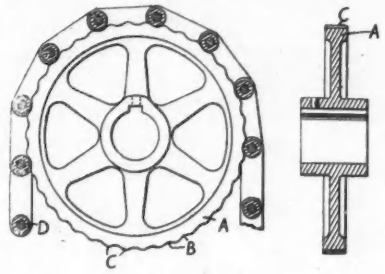
narrow radially compared with the air-belt. The partition is preferably composed of two semi-circular half portions joined by flanges *E* to enable it to be readily assembled about the cylinder or removed through a convenient opening in the outer wall of the air-belt chamber, which is normally closed by a cover plate *F*. In the partition a series of valve openings *G* is formed which are staggered with respect to the ports. They each extend axially with a flat spring leaf *H* to form an inward opening flap valve. The dimensions of the openings *G* are such that their effective area is at least 10 per cent greater than that of the ports *B*, whereby the loss in pressure of the scavenging air is reduced. The leaf spring is supported at the top by another spring leaf *J* in the shape of a hair-pin, which is bolted to the partition. The constructional details of the invention may be varied in different ways.—*September* 2, 1953.

POWER TRANSMISSION

696,624. November 7, 1951.—TRACTION WHEEL DRIVE, Sherman T. Transeau, Riverside, County of Burlington, New Jersey, U.S.A.

The invention relates to an improved traction wheel for chain drives for bucket elevators. Referring to the drawings, there is shown a traction wheel, constructed in accordance with the principles of the invention. For driving the endless chain, the periphery of the rim *A* is provided with an undulating or corrugated curvilinear surface formed by concave grooves *B* and convex projections or shoulders *C*, each of the grooves being formed on such a radius as to provide a traction surface generally complemental to the periphery of the chain barrel *D* which rides in it. The projection *C* thus formed between each pair of adjacent grooves *B* is shaped as a convex traction face of such radius as to cause it to merge smoothly into the continuing concave surfaces of the grooves *B*. While the depth of the grooves may be varied to increase or decrease the torque from the wheel to the chain, it is important that the depth should not be such as to transform the convex projections into an abutment corresponding to the action of a tooth, a construction specifically avoided by the invention. To obtain the desired releasable torque action, the depth of the grooves should be less than the radius of the barrel entering such grooves, while the curvature of each groove should be of a radius preferably, but not necessarily, equal to that of the chain link barrels. By the substantially uniform undulating surface the traction drive becomes a composite one of both torque and friction, the wheel, however, being self-releasing from the torque component when the elevator chain is subjected to overload or when its freedom of movement



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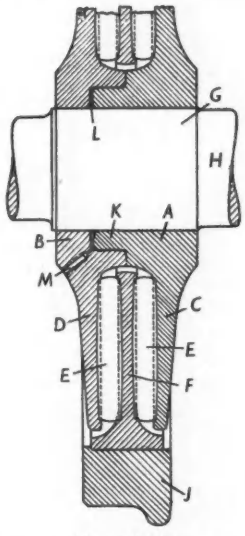
is impeded by a foreign object entering the elevator system. At least one extra "hunting" shoulder is provided in the wheel periphery which causes the chain link barrels to advance progressively about the wheel to the extent of one shoulder for each revolution of the wheel. A wheel having a number of projections or shoulders per pitch of the chain is of decided advantage in that it lessens the shock to which the wheel is subjected when the wheel and its associated chain is operating under load.—*September* 2, 1953.

RAILWAY ENGINEERING

696,627. December 20, 1951.—ROLLING STOCK WHEEL HUBS, Ruhrstahl Aktiengesellschaft, Witten/Ruhr, Germany.

The invention relates to wheel hubs for railway rolling stock rubber sprung wheels of the kind in which the hub is formed in two parts. The wheel illustrated in the drawing has a hub comprising two parts, *A* and *B*. The part *A* is integral with an outer wheel disc *C* and the hub part *B* is integral with an associated disc *D*. Rubber elements *E* are disposed and compressed axially on both sides of an annulus *F* between the outer wheel discs *C* and *D*. The two hub parts are secured to the hub



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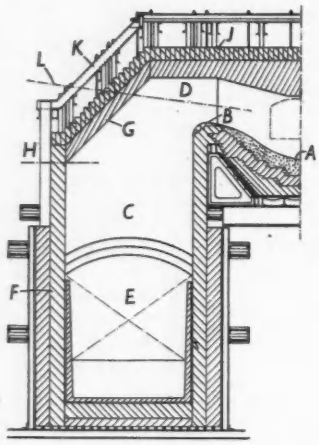
seating *G* of the wheel axle *H*, the annulus *F* carrying the tyre *J*. The hub part *A* is provided at its inner face with a projecting collar *K*, and the other hub part is provided with a mating recess into which the collar is pressed. When the wheel is assembled the collar *K* projects into the recess in the hub part *B* to a depth such that there is an annular space *L* between the end face of the collar and the base of the recess. The thickness of the collar and the inner diameter of the recess are so chosen that the mating surfaces of the hub part *A* and of the hub part *B*, respectively, produce a fluid-tight joint. A port *M* is provided in the hub part *B* and admits oil under pressure into the space *L* which constitutes a pressure chamber. The hub part *B* is thereby pushed off the hub seating outwards and without risk of canting. The hub part *A* has a greater area of contact with the hub seating and in consequence retains its position.—*September* 2, 1953.

FURNACES

696,414. July 15, 1949.—OPEN HEARTH FURNACES, Salem Engineering Company, Ltd., and Herbert Jones, both of the company's address at Milford House, Milford, near Derby.

The principal objects of the invention are to minimise the obstructions to the flow of gases through the throats of the slag pockets and the rate of deterioration of the furnace end walls. As shown in the drawing, an open hearth furnace comprises a hearth *A* having, at each end, a bridge plate *B*. Beyond each bridge plate a slag pocket *C* is built, the upper end of the pocket being in communication with the combustion zone above the hearth, through a throat *D*, and the lower end of the pocket being in communication with a regenerator through an opening *E* in one of the side walls of the pocket. The end wall *F* of each slag pocket, instead of being vertical throughout its entire height, has an upper end portion *G* which is inclined upwards and inwards towards the throat *D* at an angle of 45 deg. ; the end wall portion extends from the stage or operating-platform level, indicated at *H*, to the roof structure *J* and is suspended from a system of external and similarly



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inclined buckstays or girders *K*. The burners are built into each inclined wall portion *G* in the roof structure, the longitudinal centre lines of the burners being so positioned, as indicated by the chain-dotted line *L*, that when extended inwards they pass over the adjacent bridge plate and intersect the work-receiving surface of the hearth midway between the two bridge plates. Since the burner nozzles are located at or near the regions of the end walls which are nearest to the hearth, there is no need for the nozzles to project beyond the inner faces of the end walls, to any material extent, to enable them to be positioned in the most advantageous and efficient manner. The flow of hot gases through either throat between the hearth and the corresponding slag pocket is not obstructed to any material extent by projecting dog-houses or like water cooled structures, and the gases are brought into contact with a minimum area of water-cooled surface.—*September* 2, 1953.

Launches and Trial Trips

AUBY, cargo ship ; built by Henry Robb, Ltd., for the Sarawak Steamship Company, Ltd., Sarawak ; length between perpendiculars 212ft, breadth moulded 44ft, depth moulded to upper deck 21ft, mean draught 11ft 9in, deadweight 1170 tons, service speed 10 knots ; two holds ; two Ruston and Hornsby supercharged, four-stroke diesel engines driving through oil-operated reverse reduction gears, 1018 total b.h.p., three Ruston and Hornsby 75kW diesel-driven generators. Launch, September 24th.

TEMPLE HALL, cargo ship ; built by the Caledon Shipbuilding and Engineering Company, Ltd., for the Temple Steamship Company, Ltd. ; length between perpendiculars 425ft, breadth moulded 58ft 6in, depth to shelter deck 37ft 9in ; five cargo holds, one heavy derrick of 30 tons lift, electrical deck machinery, three 200kW diesel-driven generators, Vickers-Armstrongs-Doxford opposed-piston oil engine, four cylinders, 3600 b.h.p. Launch, September 24th.

GANGE, cargo liner ; built by the Forges et Chantiers de la Mediterranée for the Messageries Maritimes ; length between perpendiculars 445ft 7in, breadth moulded 60ft 8½in, depth moulded to shelter deck 38ft 11in, loaded draught 26ft, deadweight 8300 tons, speed 16·5 knots ; three complete decks, five holds, MacGregor steel hatch covers, one 60-ton heavy derrick, electrical deck machinery, three 250kW diesel-driven generators ; two Sulzer diesel engines, six cylinders, 720mm diameter by 1250mm stroke, each of 4200 b.h.p. at 125 r.p.m. Trial, September.

Catalogues

CAMBRIDGE INSTRUMENT COMPANY, Ltd., 13, Grosvenor Place, London, S.W.1.—Sheet No. 307, giving specifications of the standard patterns of 4in and 6in dial thermometers.

THE STANDARD AND POCHIN BROS., Ltd., Evington Valley Road, Leicester.—Publication No. 182, "Standard" plant for the removal and utilisation of wood waste.

LANCASHIRE DYNAMO AND CRYPTO, Ltd., St. Stephen's House, Victoria Embankment, London, S.W.1.—List A.1, stock and price list of a.c. motors, and List W.700, illustrated descriptive list of standard a.c. motors.

HEINRICH MEISSNER AND CO., Stuttgart-Zuffenhausen, Germany. U.K. agent and distributor, John H. Mitchell, 34, Lower Loveday Street, Birmingham, 19.—Leaflet describing "Schlegel" waste oil regenerators.

INTERNATIONAL COMBUSTION, Ltd., 19, Woburn Place, London, W.C.1.—Publication No. G525, describing industrial grinding with the Hardinge conical mill. Publication No. W537, describing "Usco" plate air heaters.

THE BRITISH ROTOTHERM COMPANY, Ltd., Merton Abbey, London, S.W.19.—Catalogue giving full details of mercury-in-steel and vapour pressure thermometers and recorders, also pressure and vacuum gauges and recorders.

Contracts

THE VULCAN FOUNDRY, Ltd., Newton-le-Willows, Lancs, has received an order from the Crown Agents for the Colonies, for forty-six 2–8–4 steam locomotives for the East African Railways. The total value of the order is roughly £1,500,000.

Forthcoming Engagements

Secretaries of Institutions, Societies, &c., desirous of having notices of meetings inserted in this column, are requested to note that, in order to make sure of their insertion, the necessary information should reach this office on, or before, the morning of the Monday of the week preceding the meetings. In all cases the TIME *and* PLACE *at which the meeting is to be held should be clearly stated.*

ASSOCIATION OF SUPERVISING ELECTRICAL ENGINEERS

Tues., Oct. 20th.—54, Station Road, New Barnet, Herts, Presidential Address, "Education and Training in the Electrical Industry," C. T. Melling.

BRITISH INSTITUTION OF RADIO ENGINEERS

Wed., Oct. 14th.—N.E. SECTION : Institution of Mining and Mechanical Engineers, Newcastle upon Tyne, "The Impact of Communication Theory on Television," D. A. Bell, 6 p.m.
Wed., Oct. 21st.—LONDON SECTION : London School of Hygiene, Keppel Street, W.C.1, Annual General Meeting, 6 p.m.

CHEMICAL SOCIETY

Thurs., Oct. 15th.—LONDON : Royal Institution, 21, Albemarle Street, W.1, "The Mechanism of Reactions between Gases and Solids," J. S. Anderson, 7.30 p.m.——BRISTOL : The University "Synthesis of Simple Peptides," F. E. King, 7 p.m.——EDINBURGH : North British Station Hotel, Joint Meeting with The Royal Institute of Chemistry and the Society of Chemical Industry, 7.30 p.m.
Fri., Oct. 23rd.—BIRMINGHAM : The University, "Analytical Errors : Heinous and Otherwise," T. B. Smith, 4.30 p.m.

INCORPORATED PLANT ENGINEERS

Mon., Oct. 12th.—DUNDEE BRANCH : Mathers Hotel, Dundee, "Factory Instrumentation" 7.30 p.m.
Tues., Oct. 13th.—MANCHESTER BRANCH : Engineers' Club, Albert Square, Manchester, "The Plant Maintenance Team's Visit to the U.S.A.," Colin Troup, 7.15 p.m.
Wed., Oct. 14th.—E. MIDLANDS BRANCH : E. Midlands Gas Board Showrooms, Parliament Street, Nottingham, "The Works Engineer and the Factories Act," 7 p.m.
Thurs., Oct. 15th.—BLACKBURN BRANCH : Grosvenor Hotel, Lord Street, Blackburn, "Gunite in Industrial Building Maintenance," G. N. Ternan, 7.30 p.m.
Mon., Oct. 19th.—MERSEYSIDE AND NORTH WALES BRANCH : Radiant House, Bold Street, Liverpool, "Design of a Central Heating System," N. Woodhead, 7.15 p.m.
Tues., Oct. 20th.—SOUTH WALES BRANCH : Mackworth Hotel, Swansea, "Lubrication," talk and films by courtesy of Shell Mex and B.P., Ltd.

INSTITUTE OF BRITISH FOUNDRYMEN

Wed., Oct. 28th.—LONDON BRANCH : Waldorf Hotel, Aldwych, W.C.2, "Shell Moulding," A. Emmerson, 7.30 p.m.

INSTITUTE OF MARINE ENGINEERS

Tues., Oct. 13th.—85, Minories, London, E.C.3, "Operation of a Gas Turbine under Sea Conditions," J. Lamb, 5.30 p.m.

INSTITUTE OF PETROLEUM

Wed., Oct. 14th.—26, Portland Place, London, W.1, Redwood Lecture, "The Friction of Solids," F. P. Bowden, 5.30 p.m.

INSTITUTE OF REFRIGERATION

Tues., Oct. 20th.—Storey's Gate, St. James's Park, London, S.W.1, "Insulation Testing," H. S. Hatfield and L. A. Smith, 5.30 p.m.

INSTITUTE OF ROAD TRANSPORT ENGINEERS

To-day, Oct. 9th.—S. WALES GROUP : B.O.C. Works, Birchgroveon, Caerphilly Road, Cardiff, "Welding Methods," 7 p.m.
Tues., Oct. 13th.—MIDLANDS CENTRE : Crown Inn, Broad Street, Birmingham, "Ball and Roller Bearings for Road Transport," M. J. Knaggs, 7.30 p.m.
Wed., Oct. 14th.—E. MIDLANDS CENTRE : Mechanics Institute, Nottingham, "Hydraulic Servo Systems for Heavy Commercial Vehicles," J. St. H. Webb, 7.30 p.m.
Thurs., Oct. 15th.—YORKSHIRE CENTRE : Hotel Metropole, Leeds, "The Maintenance of High Speed Diesel Engines," H. L. Parrish, 7.30 p.m.

INSTITUTE OF TRANSPORT

Mon., Oct. 12th.—SUSSEX GROUP : The Royal Pavilion, Brighton, "Trends and Influences in Transport Charges," J. R. Pile, 6.30 p.m.——YORK GRADUATE AND STUDENT SOCIETY : Railway Headquarters, York, "Modern Methods of Goods Handling," J. Winter, 7.30 p.m.
Tues., Oct. 13th.—ESSEX GROUP : Shire Hall, Chelmsford, "London, Tilbury and Southend Railway," W. O. Reynolds, 7 p.m.
Wed., Oct. 14th.—SOUTHERN SECTION : Harbour Board Offices, Southampton, "Looking Ahead in Transport," W. C. Reakes, 5 p.m.

INSTITUTE OF WELDING

Sat., Oct. 24th.—SOUTH LONDON BRANCH : Visit to G. A. Harvey & Co., Ltd., Greenwich.

INSTITUTION OF BRITISH AGRICULTURAL ENGINEERS

Tues., Oct. 13th.—Institution of Electrical Engineers, Savoy Place, London, W.C.2, Presidential Address, D. P. Ransome, 2.15 p.m.

INSTITUTION OF CHEMICAL ENGINEERS

Sat., Oct. 10th.—Reynolds Hall, College of Technology, Manchester, George E. Davis Memorial Lecture, Norman Swindin, 3 p.m.
Sat., Oct. 17th.—MIDLANDS BRANCH : The University, Edmund Street, Birmingham, "Some Aspects of Chemical Engineering in the Manufacture of Man-Made Fibres," W. G. Daroux, 3 p.m.

INSTITUTION OF CIVIL ENGINEERS

Tues., Oct. 13th.—Great George Street, Westminster, London, S.W.1, "The Effect of Jet Aircraft on Airfield Pavements, and Associated Problems," D. H. Carrack and D. G. Robertson 5.30 p.m.
Tues., Oct. 20th.—Great George Street, Westminster, London, S.W.1, "The Measurement and Utilisation of the Water Resources of the Nile Basin," W. E. Hurst, 5.30 p.m.

INSTITUTION OF ELECTRICAL ENGINEERS

Tues., Oct. 13th.—Savoy Place, London, W.C.2, Discussion, "How Should the Action of Polyphase Commutator Motors be Approached ?" opened by I. L. Stefani, 6 p.m.
Wed., Oct. 14th.—RADIO SECTION : Savoy Place, London, W.C.2, Chairman's Address, 5.30 p.m.
Mon., Oct. 19th.—Savoy Place, London, W.C.2, Discussion on "Television," to be opened by chairman.

INSTITUTION OF ENGINEERS AND SHIPBUILDERS IN SCOTLAND

Tues., Oct. 20th.—39, Elmbank Crescent, Glasgow, "Standardisation of Diesel-Electric Power Packs," J. C. Macfarlane, J. W. Macfarlane and W. I. Macfarlane, 6.30 p.m.

INSTITUTION OF LOCOMOTIVE ENGINEERS

Wed., Oct. 21st.—Inst. of Mechanical Engineers, Storey's Gate, S.W.1, "Production of Steel Wagons," W. Vandy, 5.30 p.m.

INSTITUTION OF MECHANICAL ENGINEERS

Thurs., Oct. 15th.—Annual Dinner at the Dorchester Hotel, Park Lane, W.1, 7 for 7.30 p.m.
Fri., Oct. 16th.—Storey's Gate, St. James's Park, London, S.W.1 General Meeting, Presidential Address by A. Roebuck, 5.30 p.m.

INSTITUTION OF MINING AND METALLURGY

Thurs., Oct. 15th.—Geological Society of London, Burlington House, London, W.1, "The Technique of Mine Valuation in some Special Cases," Jack Spalding, "The Underground Water Encountered at Blyvooruitzicht Gold Mine," R. C. Curtin, 5 p.m.

INSTITUTION OF POST OFFICE ELECTRICAL ENGINEERS

Tues., Nov. 10th.—Conference Room, 4th Floor, Waterloo Bridge House, S.E.1, "The Influence of Signal Imitation on the Design of V.F. Signalling Systems," S. Welch, 5 p.m.

JUNIOR INSTITUTION OF ENGINEERS

To-day, Oct. 9th.—Townsend House, Greycoat Place, London, S.W.1, "Industrial and Marine Gas Turbines," A. W. Pope, 7 p.m.

LIVERPOOL JOINT CHEMISTRY COMMITTEE

Wed., Oct. 21st.—Grosvenor Hotel, Chester, "Discovery and Development of an Oilfield," H. R. Lovely, 7.30 p.m.

MANCHESTER ASSOCIATION OF ENGINEERS

Fri., Oct. 16th.—The Engineers' Club, Albert Square, Manchester, "The Formation and Prevention of Atmospheric Contamination in Factories," W. A. Attwood and W. B. Lawrie, 6.45 p.m.

OLD CENTRALIANS

Wed., Oct. 14th.—Chez Auguste Restaurant, Old Centralians Luncheon, W. R. Cook on "Rocket Reminiscences," 12.45 p.m

ROYAL STATISTICAL SOCIETY

Wed., Oct. 14th.—Lighting Service Bureau, 2, Savoy Hill, London, W.C.2, "Some Problems in Questioning, Illustrated by a Recent Enquiry about the Third Programme," B. Emmett, 6 p.m.

SHEET AND STRIP METAL USERS' TECHNICAL ASSOCIATION

Wed., Oct. 14th, to Fri., Oct. 16th.—Hardness Testing Conference to be held in the Memorial Hall, City Hall, Sheffield.

SHEFFIELD SOCIETY OF ENGINEERS AND METALLURGISTS

Mon., Oct. 19th.—The University Building, St. George's Square, Sheffield, "Control Valves for Direct Hydraulic Presses and the Application of the System to a 1000-ton Forging Press," F. H. Fowler, 7.30 p.m.

SOCIETY OF CHEMICAL INDUSTRY

Thurs., Oct. 15th.—11, Upper Belgrave Street, London, S.W.1, "Coated Macadam—Its Manufacture and Uses," A. J. Lydon, 6 p.m.

TELEVISION SOCIETY

To-day, Oct. 9th.—Cinematograph Exhibitors' Association, 164, Shaftsbury Avenue, London, W.C.2, "Recording Television Programmes," C. B. B. Wood, 7 p.m.
Thurs., Oct. 22nd.—Cinematograph Exhibitors' Association, 164, Shaftsbury Avenue, London, W.C.2, "Flywheel Synchronising and Scanning Circuits," H. Fairhurst, 7 p.m.